Livelihoods and Fishing Strategies of Small-scale Fishing Households Faced with Resource Decline: A Case Study of Singkarak Lake, West Sumatra, Indonesia

by

Yuerlita

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Examination Committee: Dr. Sylvain R. Perret (Chairperson)
Prof. Ganesh P. Shivakoti
Dr. Clemens Grunbuhel

External Examiner: Dr. Bruno Barbier
International Institute for Water and Environmental Engineering
Ouagadougou - Burkina-Faso

Nationality: Indonesian
Previous Degree: Master of Science in
Natural Resources Management
Andalas University
Indonesia

Scholarship Donor: Ford Foundation/ Andalas University, Indonesia – AIT Fellowship

Asian Institute of Technology
School of Environment, Resources and Development
Thailand
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Abstract

Small-scale inland fisheries (SSIF) provide food and income to millions of rural poor worldwide. However, their existence and roles are often overlooked in the development planning and their contribution to wider economic development is undervalued. Fish resource decline and environmental degradation threatened the livelihoods. Overfishing and ill fishing practices are common. The Singkarak lake (West Sumatra) exemplifies this sustainability challenge, where natural resources and livelihoods closely interact. The overall objective of this study is to document, model and discuss the actual diversity in livelihoods, fishing practices and performance of SSIF along the Singkarak Lake under the changing lake environmental condition and depletion of fisheries resources. The specific objectives of the study are (1) to explore inland fish capture system in terms of fish resources, resource users, and its current management; (b) to develop a model that represents the diversity of small-scale fishing communities, to identify the main socio-economic and technical indicators that contrast the livelihood of small-scale fishing household, to reveal the main livelihood strategies at play; (c) to analyze household's efficiency in fishing, to reveal their fishing strategies.

A reconnaissance survey was conducted between January and March 2009 to obtain an overview of the lake's physical environment, the institutional setting, the livelihoods and the overall fishing practices and issues. The primary data were collected between April and December 2009 in three fieldwork stages by performing informant interviews, focus group discussions and household surveys, respectively in each of these stages. Based upon a sample of 200 households, a typology is developed by using multivariate analyses (Principal Component Analysis and Cluster Analysis). The technical efficiency analysis was performed using data envelopment analysis (DEA).

Fishing activities are performed on a daily basis throughout the year. The primary target and catch is an endemic species called *bilih* (*Mystacoleucus Padangensis*), which has high commercial value. Two types of fishing gear are commonly used: set gillnets and cast nets. Dragnets are also used. While all parties confirm the decline of the fish resource, they have different diagnoses to explain the causes. Experts and scientists point out overfishing and unsustainable (and illegal) fishing practices, while fishers allude to water quality decline and increased competition between uses, including hydropower.

The fishers were classified into different types characterized by distinct livelihood strategies. Three household types are identified, namely "farming fishers" households (type I, 30%), "fishing farmers" households (type II, 30%), and "mainly fishers" households (type III, 40%). There are significant differences among these groups in the number of boats owned, annual fishing income, agriculture income and farming experience. Type-I consists of farming fishers, well equipped, with high fishing costs and income, yet with the lowest return on fishing assets. They are also landowners with farming income, showing the lowest return on land capital. Type-II includes poor fishing farmers, landowners with higher farming income; they show the highest return on land asset. They have less fishing equipment, costs and income. Type-III (mainly fishers) consists of poorer, younger fishers, with highest return on fishing assets and on fishing costs. They have little land, low farming income, and diversified livelihood sources.

The analysis of technical efficiency shows that average fishing efficiency of all fishing households is 75% yet with marked differences between types. It also reveals the different fishing strategies. Overall, only about half (51%) of households are considered efficient. Paradoxically, type-I households have the lowest technical efficiency in fishing (54% on average), revealing an over-capitalization strategy. They are inefficient in using all selected inputs, especially showing excessive fishing costs and number of boats, with regards to catches. In the two other types, the prevailing source of inefficiency is excessive fishing operational costs. Type-II households show a least vulnerable livelihood system, with high technical fishing efficiency (88%), and high farming income. Findings are compiled and summarized using the DPSIR framework, which highlights causal relationships and pathways between drivers, pressures, states, impacts and responses in the case of fish resource decline of Singkarak lake. In view of the overall decline in fish resources, and relative land availability, results suggest that developmental efforts should focus first on reducing fishing efforts in type I households, and possibly promoting a shift towards more farming. This may be achieved through the enforcement of existing restrictions on net mesh size. It would affect catches by all types but primarily would reduce type I effort, promote farming in this type and result in potential fish resource protection overall.

Keywords: livelihoods, fishing strategies, efficiency, inland fisheries, small-scale fishers, typology, Singkarak Lake

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Chapter 1

Introduction

1.1 General background

Inland aquatic ecosystems, both natural (such as lakes, rivers, streams, wetlands, and floodplains) and manmade (including reservoirs and rice fields) play an important role in people's livelihoods in many parts of the world. This is due to their ability to supply various services for humans to support the sustainability of environment and people's livelihood. It is recorded that 92% of the world's inland fisheries catches come from developing countries, most of which are from small-scale fisheries (DFID, 2002).

Inland fisheries play an important role as a source of food supply in order to enhance food security and generate the households' income. Asia is the top producer of inland capture fisheries, which accounts for 5.8 million tons out of 8.7 million tons of the total world's inland capture fisheries in 2001 (FAO, 2003b). Although the exact number of people involved in inland fisheries is unknown, it is assumed that millions of people are involved in this sector (DFID, 2002). It provides employment opportunities not only from fishing but also from fishing related activities such as fish processing, transporting and trading, net repair, and boat making which is carried out mostly at small-scale level. Small-scale inland fisheries (SSIF) are closely linked to other income generating activities such as farming, livestock rearing, and various non-farming activities.

Despite the important contribution of SSIF, their existence and roles are often overlooked in development planning and their contribution to wider economic development is undervalued. Yet, overfishing and ill fishing practices seem to be fairly common, including non-selective fishing gears, ghost fishing, overexploitation, the use of dynamite, and poisons. Reasons often mentioned include overall lack of information and awareness regarding ecosystems' status, fish populations' status, poor education and skills on the side of the fishing communities, and lack of local institutional arrangements regulating freshwater fisheries. In addition to poor management practice and unsustainable exploitation of fisheries, environmental problems such as pollution and eutrophication are some other problems related to inland aquatic ecosystem including fisheries and aquaculture (Odada et al., 2004). Water quality and quantity depletion could happen as the result of agricultural expansion and development of hydroelectric power as is happening in several lakes in Greece (Birol et al., 2006). Infilling and drainage, invasive species, and global warming are some of the pressures behind the changes in the lake's ecosystem (UNEP, 2008). Overall, inland water ecosystems are facing major threats all over the world including modification of river systems, water scarcity, and fisheries exploitation, pollution, eutrophication and the impact of climate change (Allan et al., 2005; Allan & Flecker, 1993; Malmqvist & Rundle, 2002; Revenga & Kura, 2003).

Conventional fisheries management has often failed to address current fisheries problems which result from complex human/nature relationship (Allison & Ellis, 2001). It also has limited capacity to integrate complex factors in fisheries including socio, economic, and ecological factors (Garcia & Charles, 2007). Conventional approach sees complex environmental problems from socio and ecological perspectives separately, jeopardizing the recommendation proposed for the management option. Conventional approach also results in panacea solution which adopts “single governance system blue print” for all environmental problems such as privatization and communal ownership (Ostrom et al., 2007). There are four main inter linkages indicators needed to consider in order to ensure the sustainability of fisheries system namely, ecological, economic, community, and policy (Adrianto et al., 2005). Sustainability of fishery system cannot be achieved from stand alone conservation but should incorporate social or fishing communities also (Charles, 1994). It reflects the importance of considering human as the insider to the ecosystem. Analyzing environmental problems only from social perspective, people might be able to adapt with the changes but such adaptation will perhaps come at the expense of the ecosystem adapting with the changes (Smit & Wandel, 2006). In addition, ecology based decision making would result in a narrow and wrong conclusion leading to inappropriate management strategy. Effective management of small-scale fisheries requires incorporation of multi perspective, involving all stakeholders, and considering governance within society (Andrew & Evans, 2009). It is in line with management objectives stated by FAO in Code of Conduct for responsible fisheries emphasizing that social, economic and institutional factors must be incorporated in fisheries management to ensure its sustainability (FAO, 1995).

If guidance and policy measures from code of conduct for responsible fisheries are widely implemented, it can be expected that millions of small-scale fishing communities would be able to improve their living standards and more secure livelihoods. However, in most cases, policy environment governing SSIF tends to make the poor more vulnerable and marginalizes many people involved in this sector (DFID, 2002). Most governments in developing countries fail to consider the socio-economic potential of small-scale fisheries, their needs, concerns, and constraints (Allison & Ellis, 2001; Berkes, 2003; Berkes et al., 2001; McConney & Mahon, 1998; Smith et al., 2005) and do not pay much attention to their management, as the sector features specific economic, social and cultural attributes: the sector is informal, ill-organized; labor force is unskilled and scattered; livelihood system are diverse and dynamic, unspecialized marketing networks are poorly-documented and overall economic weight is not known clearly.

1.2 Statement of the problem

The study was carried out in Singkarak Lake fishing communities. Over the last two decades or so, the lake has come under increasing pressure of interlinked anthropogenic issues (i.e water pollution, eutrophication, depletion of water level, erosion, sedimentation, and overfishing) and environmental trends (i.e lake upwelling and flooding, declining fish resources). These problems interconnect and impact onto each other. The deterioration of water quality due to pollution has caused the decline of fishing sector. Particularly, the habitat of endemic fish called “ikan bilih” (*Mystacoleucus padangensis*) has been distressed by the contaminants. In addition, degradation at the catchment area has accelerated erosion and sedimentation in the lake which in turn has damaged the littoral zone as the reproduction and breeding area of bilih fish. Depletion and fluctuation of lake water has caused changes in productivity of many water uses including the decrease of water supply for hydroelectric power plants and agriculture. Overfishing and destructive fishing practices are also observed. This condition has affected the livelihoods of riparian communities most of which depend on the lake’s ecosystem, particularly small-scale fishing community due to declining fish catch.

From the problems stated above, it can be ascertained that Singkarak Lake ecosystem is facing environmental changes that impact the diversity and its ability to provide ecosystem services to the people. The problem leads to socio-economic issues since most of the people living at the lakeshore highly depend on the lake for fishing. It becomes more complex because it is a transboundary lake and it involves political issues. Currently, the lake is managed by a steering committee at provincial level. However, there has not been a particular law or regulation for the management of the lake and its catchment. There is currently no legal or institutional solution proposed to solve the problems in Singkarak Lake (Farida et al., 2005).

Policies tend to consider that fishing communities are homogenous while diversity and dynamics are more often the case because they are facing a hard situation; struggling with declining resources and keep developing adaptive and coping strategies (Bene, 2009; Brugère et al., 2008; Neiland et al., 2000). There seem to exist pattern of adaptation among the fishers in Singkarak lake; some households seem to diversify their livelihoods towards farming while others remain mostly fishers; some are intensifying fishing activities while some stick to traditional ways.

This study address the two phenomena of the fishers under the declining resources. Which fishers choose which livelihood strategy and practices, what are the reasons of their decision and what the outcomes. It is assumed that the livelihood patterns of the fishers vary in line with the variability of their socio-economic characteristics. Also, intensifying fishing activities may help keep catches high enough to sustain livelihoods but threaten the declining resources which impacted upon their livelihoods. It is a cycle-like problem between resource decline and strategies of the fishers as the response to the decline.

1.3 Research objectives

In view of the situation, the main research questions addressed by this study are:

- What are the main socio-economic and technical factors contrasting small-scale fishing communities around Singkarak Lake? and

- What are the livelihood strategies employed and what are the fishing strategies and practices at play? Can they meet the challenges and help solve the issues?

The overall objective is to document, model and discuss the actual diversity in livelihoods, practices and performance of the fishers along the Singkarak Lake under the changing lake environmental condition and depletion of fisheries resources.

The specific objectives of the study are:

1. To explore inland capture system in terms of characteristic of fisheries resources, resource users and its current management;
2. To develop a model that represents the diversity of small-scale fishing communities, to identify the main socio-economic and technical indicators that contrast the livelihood of small-scale fishing household, to reveal the main livelihood strategies at play;
3. To analyze household’s efficiency in fishing, to reveal their fishing strategies.

1.4 Rationale of the study

Indonesia has a large coverage area of inland water resources, which is estimated at 14 million hectares comprising of 220 rivers and 50 big lakes. It is one of the largest producers of inland fisheries after China, India, Bangladesh, and Cambodia (DFID, 2002). Furthermore, Indonesia is one of the countries that have a significant number of fishers and fish farmers and is the third ranking producer of marine and inland fisheries in the world with total marine and inland fish production of 5 million tons in 2008 (FAO, 2010). While for the inland capture fisheries, Indonesia ranks number seven with a total production of 323,150 tons in 2008. Nevertheless, over the last 40 years fisheries resources in Indonesia have rigorously depleted, one of the main factors being the inability of the Indonesian government to enforce fisheries regulation and their limited ability in fisheries management policy formulation (Heazle & Butcher, 2007). Inland capture fisheries management in Indonesia is still based on a general policy to maintain the resources; there is no particular national management policy (Coates, 2002).

The focus of this study is an important contribution to the body of knowledge about the influence of social and economic factors on SSIF management practices in the following two ways: first, it is a comprehensive investigation of environmental changes impacted into small-scale fishers livelihoods, reporting in descriptive and statistical analyses. Second, it seeks to address special particular concerns due to the lack of diversity of rural households and lack of socio-economic data of the fishers within the study area. From what has been reviewed from available documents and literature on this site, there are lots of studies related to the ecology and reproduction of *bilih* fish that have suggested conservation and fish re-stoking as the appropriate solution for fisheries problem in Singkarak Lake (Dewi, 1995; Fauzi, 1995; Gustam, 1995; Juita, 1995; Maiyarni, 1997; Syandri, 1996; Syandri, 2002; Syandri et al., 2002a; Syandri et al., 2002b). However, those studies lack an analysis of fishers' livelihoods, diversity, resource dynamics and their concerns on depleted resources. Some other research also comes up with suggestions regarding *bilih* fish conservation and introduction of bilih fish as endemic species to another lake in North Sumatra (Kartamihardja & Purnomo, 2006; Patriono et al., 2010; Purnomo et al., 2003b) which is still concerning the ecological view of fishery management.

Inland capture fisheries in Southeast Asia are characterized by diversity in the mode of their operation, environment in which they are operated, and complex social and cultural societies (Coates, 2002). Most small-scale fishers are attached to various livelihood strategies which might influence the mode of their fishing operation and the perceptions on the current fisheries resource. The dearth of understanding on the socio-economic factors and the livelihoods of fishers as the main stakeholders have driven the need of the present study. It highlights the diversity and livelihoods of the fishers in an attempt to fill data gap for Singkarak Lake management in particular and generally for inland water resources in Indonesia. An appropriate management is highly required for Singkarak Lake to avoid wider and deeper degradation and its impact on environment and its dependants.

1.5 Scope and limitation

The study analyzes local riparian livelihood strategies focusing on small scale-fishers under threat of fish catch depletion. This relationship will be described by analyzing the impact of environmental changes to livelihoods strategy. The overall objective of the study is to investigate the livelihood of small-scale fishers in Singkarak Lake and how are their strategies dealing with declining resources. Thus, the study focuses on characteristics of inland fisheries and the socio-economic aspect. There are 3 main aspects of inland fisheries which have been assessed: 1) characteristics of fisheries resources, fishers, fisheries communities and related problems or constrained. 2) diversity of fishing households by developing typology of the fishers. 3) fishing strategies (through technical efficiency analysis in mobilizing several inputs to produce maximum level of output. Although the study contributes to policy direction to address complex socio-ecological issues of lake ecosystem, some information gaps and understanding is still remain from this study. This study did not monitor ecological aspect of the lake resources. Most of the ecological data are cited from secondary sources.

1.6 Dissertation Overview

The dissertation consists of nine chapters. In chapter 1, research background, problems, main questions and research objectives, rationale, scope and limitation of research is presented. It reviews the importance of small-scale fisheries to economic development, in particular for developing countries and current problem related to inland-small scale fisheries. It is followed by brief overview of current status and problem of inland fisheries in the study area.

Chapter 2 covers relevant theories, concepts and literature search with regards to SSIF management and its implication in developing countries.

Chapter 3 is presented with conceptual framework, research method, sampling strategy adopted in this research and methods applied for data analysis. The study is based on the conceptual framework for understanding determinants of livelihood outcomes in inland fisheries developed by Smith et al (2005). The framework comprises of three main components namely situational variables, patterns of interaction and livelihood outcomes.

Chapter 4 describes the study area, including the biophysical features of the lake and its basin area, socio-economic, cultural and political setting. Moreover, it presents the background of the research site in terms demography, land-use surrounding the lake and its basin area, development project that have been implemented surrounding the Lake.

Chapter 5 presents fishery and fishers characteristics of Singkarak lake. It covers physical attributes of Singkarak lake, fishing technical and biological attributes. Further it discusses about the lake environmental condition and fisheries resources.

Chapter 6 identifies and documents the primary livelihood systems and the strategic adaptations involved in fishing communities. The typology of the fishers is developed with implementation of multivariate analysis. The nature of their livelihood strategies is discussed for each identified group.

Chapter 7 reveals fishing strategies through measurement of technical efficiency. Non-parametric approach, Data Envelopment Analysis (DEA) is applied as analytical tool. Technical efficiency between the types is discussed and concludes with the potential inputs reduction to achieve full efficiency.

Chapter 8 summarizes the research findings into comprehensive approaches for enhanced support to households in riparian fishing and farming sector in Singkarak Lake and improved management of both resource and local development. The summary is presented in more comprehensive DPSIR framework; integration of DPSI analysis and the response (R) of the fishers from livelihood analysis.

Chapter 2

Literature Review

Management of inland waters has received less attention in global fisheries debates and has been poorly understood and documented while this sector supports the livelihoods of many rural poor, particularly in developing countries. Considering the complexities and circumstances of inland fisheries and its dependants, it is important to discuss inland fisheries in terms of their importance, challenges and characteristics. This chapter also examines socio-economic issues of small-scale fisheries livelihood and problems encountered. The focus is on the relationship between the decline of fish resources and various socio-economic factors operating in this community. Moreover, it briefly presents some concepts and theories related to small-scale fisheries management around the globe, with an emphasis on Southeast Asia.

2.1 The importance, challenges and characteristics of inland small-scale fisheries

Inland fisheries provide food, employment opportunities, cash income, and contribute to poverty reduction in many developing countries (Allison et al., 2002; Bene, 2009; Sarch & Allison, 2001; Smith et al., 2005; Thorpe et al., 2005). Although small-scale fisheries typically feature small catches per unit, cumulative catches exceed commercial and mid-sized fisheries in many areas (Coates, 2002). Fish account for the bulk of animal protein consumed in countries such as Laos, Bangladesh and Cambodia (Smith et al., 2005); in Asia, half of all fish-based food is derived from small-scale fisheries (FAO, 2005). Poor households are highly dependent on fisheries as a protein source for family consumption and as a source of cash income, not only for fishers but also for farming fishers (Bene et al., 2009). Due to the ability of fishing to provide daily cash-income for households, Bene et al (2009) refer to fish as “bank in the water.” Overall, inland fisheries play an important role in the development of regional economies through employment opportunities (Neiland et al., 2000).

Small-scale fisheries feature spatial and temporal disparities, scattered along the coastal area, with a variety of target species, fishing gears and modes of operation. In many cases, the fishers not only fish but also engage in other types of livelihood strategies. Inland fisheries are also varied in social and economic context (Allan et al., 2005). This condition confirms the heterogeneity and complexity of small-scale fisheries which have to be taken into account for appropriate fisheries management (Neiland et al., 2000; Tzanatos et al., 2005). Lack of data and information, together with complex socio-economic conditions result in the poor management, leading to marginalization of this sector. They are marginalized because of their socio-economic, geographic condition and politically get less attention from decision-makers (Pauly, 1997). Marginalization could be observed from lack of access to credit, poor roads, transportation and other types of infrastructure because they live in remote rural areas. In contrast to large-scale industrial fisheries, small-scale fishers engage in fishing with little capital and minimal access to technology (Sowman, 2006). This yields lower fishing capacity as they use smaller, non-motorized fishing vessels that are mostly operated by family labor through labor-intensive practices (FAO, 2005; Kent, 1997; Kuperan & Abdullah, 1994).

Despite such important socio-economic contributions, the issues faced and the changes at play, the role, operation modes, and performances of SSIF remain poorly documented (Bene et al., 2009).

2.2 Inland fisheries, fish resources and poverty

The studies of poverty and vulnerability of small-scale fisheries have been increasingly recognized. Discussion of poverty-related issues within this sector has been widely developed. There are two views of scholars in defining the relationship between poverty and small-scale fishers. The first interpretation of poverty and fisheries states that "*fishermen are the poorest among the poor*" and secondly, "*fishing is the activity of the last resort*" (Bailey, 1982; Panayotou, 1982; Smith, 1979). Both views is discussed and recent progress of the literature presented to arrive at a new paradigm for understanding the relationship between fisheries and poverty.

2.2.1 Fishermen are the poorest among the poor

The rural poor community greatly depends on common pool resources for their livelihood (Narayan et al., 2000). One of the most valuable resources in many parts of the world is either inland or marine fishery. The nature of inland fisheries as an open resource prompted the choice of the poor to earn money from fishing; hence, more and more people become fishers. This condition leads to overexploitation of fish resources. This phenomena is rooted in the concept of the "tragedy of the commons" developed by Hardin (1968). This model/concept explains that any common resources including river, sea and grazing area are subject to degradation. It predicts the consequences of resource extinction due to lack of control from its users to restrict resource use for personal benefit. Hardin (1968) explained this paradigm by giving an example of open-access pasture land, where herdsmen maximized individual gains by grazing as many cattle as possible. The herdsmen's greed caused natural resource depletion and threatened the livelihood of the resource users themselves.

> *…..Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all…. (Hardin, 1968)*

Although some recent works have criticized and rejected the theory of Hardin (1968) concerning common properties resources (Berkes, 1985; Feeny et al., 1990), this paradigm is a useful concept in analyzing depleted fisheries resources. In the fisheries, the commons paradigm might occur when fishermen find that fishing in a particular place is profitable, then more and more new fishers come to fish in that place, increasing efforts because more people would affect the number of catch after a certain period of time. When fishers tend to increase their efforts, efficiency problems and resource extraction take place. Intensive fish harvesting, beyond the ability of the fish to reproduce, and increasing fishing efforts results in overfishing and fish depletion (Allan et al., 2005; Stobutzki et al., 2006). Open access resource is one of the many factors contributing to overfishing which then decreases fisher productivity hence reducing income (Allan et al., 2005; Kurien, 1991). Overfishing has a significant impact on the availability of employment in fisheries and the living standard of dependant households (Bailey & Jentoft, 1990). Furthermore, FAO (2000) states that "…open access characteristic of many marine and inland fisheries is one of the important causes for widespread and persistent poverty in fisheries". Bene (2003) considers this one of the endogenous causes of poverty in small-scale fisheries. It could be also the other way, poverty in fisheries rooted outside of fisheries including broader economic development and accessibility of alternative income source (Cunningham, 1994; Kronen et al., 2010). Moreover Smith (1979) and Panayotou (1982) have emphasized that fishers are poor because of the lack of alternatives and limited access to other income generating activities. Hence, the review from Bene (2003) categorizes those factors as the exogenous causes of poverty in fisheries. Both endogenous and exogenous circumstances of poverty in fisheries encompass the link of open access resource, resource degradation, and availability of alternative income sources.

However, the factors of institutional arrangement and cultural are missing from Hardin's theory which have to be incorporated for a more comprehensive prediction and theory of resources used (Feeny et al., 1990). Stillman (1975) in Berkes (1985) argue that the tragedy of the commons occurs in three conditions: the resource users are greedy and selfish (pursuing private gain against the interest of whole community), the resource must be limited and resource extraction goes beyond the natural ability of the resource to replenish, the resource must be totally open-access to any users. Despite the debate of the commons paradigm in resources including fisheries and its analysis in explaining open access nature fisheries, resource depletion and poverty, it is recognized that fisheries exploitation has been rapidly occurring, which jeopardizes the livelihood of its dependants.

2.2.2 Fishing is the activity of last resort

There is some evidence from past research showing that fishing is the last choice of economic activities. This view signifies that people do not have any access and/or ability to pursue other livelihood options due to some limitations such as having no access to land, low education, and lack of skills. For example, the case of Peruvian highlanders, pastoralists in Senegal, and farmers in the Philippines who enter fisheries because of land degradation and limited access to grazing land (Pauly, 1997). Pollnac and Sutinen (1979) in Panayotou (1982) state that "fishing is viewed as the employment of last resort … people fish when farming is not feasible". Moreover, the number of fishers in Southeast Asia was reported to increase in significant numbers prompted by the open-access nature of fisheries in most of Southeast Asian countries (Pauly, 1979). Therefore, people turned to fishing when they were unable to pursue other income activities due to limited access, lack of capital and hence limited alternative income opportunities. This condition is very beneficial in creating employment opportunities but at the same time it is a threat for the fisheries resource. Increasing number of fishers is the main cause of resource depletion particularly in Southeast Asia (Pauly, 1979).

Both paradigms that fishermen are the poorest among the poor, and fishing is the activity of last resort have the same perception that "fisheries is poverty". This argument is an old paradigm which might have developed to other schools of thought in defining poverty in small-scale fisheries.

2.2.3 Toward new perceptions of poverty in small-scale fisheries

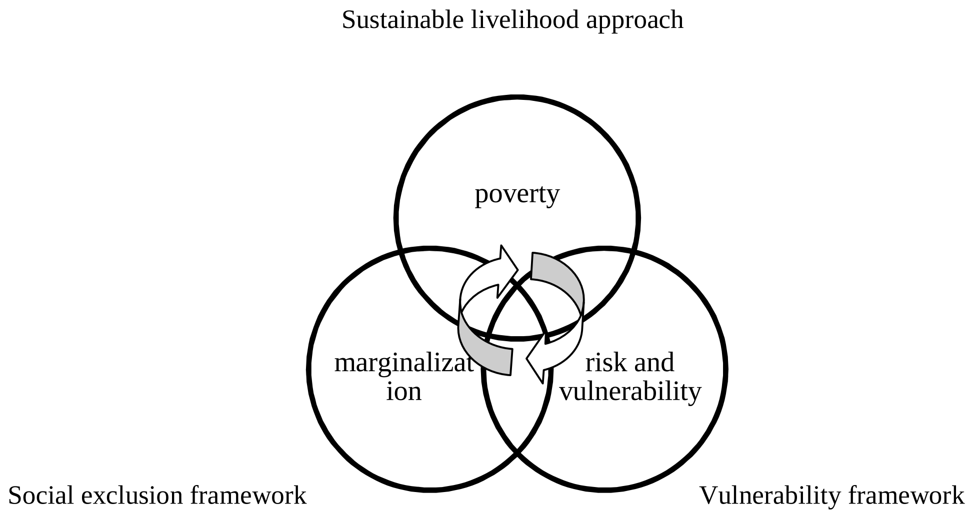
The development fisheries and poverty issue has resulted in many different perceptions in understanding poverty in small-scale fisheries. There is no systematic and linear relationship between fishing and poverty (Bene & Friend, 2011; Bene et al., 2010) but development narratives still refer to fishers as the poorest community. Such as the commonly accepted notion that “fishing is the last resort” for rural poor (Panayotou, 1982) and they are marginalized (Pauly, 1997), may not always be necessarily the case (Allison et al., 2002; Garaway, 2005). Although fisheries resource is commonly open-access resource and claimed as the occupation of last resort with fishers being the poorest among the poor, fishing is still a promising income generating activity. Moreover, it is not only a form of subsistence because it is believed that involvement in fisheries depends on the ability to raise capital for investment and labor opportunities created by the investment (Allison et al., 2002). Fishers cannot simply be defined as the poorest of the poor. While fishing is indeed the main component of fishers’ livelihood, there are different socio-economic groups (Garaway, 2005). The relation of fisheries and poverty is complex while it is not always very well understood and reflected in many studies of fisheries (Bene, 2003).

> “Fishers are not poor because they are fishers, but they are unable to diversify their livelihood hence they are vulnerable to any stresses and shocks of their activities” (Bene & Friend, 2011)
>
> “…they are poor because of their lack access to alternative employment opportunities with handsome income” (Chowdhury et al., 2011)
>
> “…the fishermen are the poorest of the poor” or “the fishery is the activity of last resort” do not reflect the complexity of the real situation” (Bene, Neiland, et al., 2003)

A more comprehensive approach is therefore required that can address poverty in small-scale fisheries taking into account the complexity of this sector and wider characteristics of poverty. Vulnerability and marginalization are two other dimensions of the impoverishment process in small-scale fishing communities hence poverty it is not considered as a standalone concept (Allison et al., 2006). Fishers do not consider themselves as the poor as long as they have access to fisheries because they can get food and basic needs from fishing, even if they are vulnerable to hazards and stresses (Salas et al., 2011).

Rakodi (1999) defined vulnerability as insecurity, how do people react to the risks and negative changes of environment, economic, social or political conditions. The concept of vulnerability has been commonly used in the field of food security and climate change. It is defined as the exposure to risks which affect livelihood systems of resource dependants and the way they adapt to the risks by utilizing their assets and capabilities.

In the case of fisheries, fishers particularly those operate at small-scale are vulnerable due to hazards and stresses (Salas et al., 2011). The hazards could be caused from exogenous (for example increasing number of fishers, water level fluctuation, hurricane) and endogenous factors (such as illegal fishing practices, limited access to other income sources). Hall (2011) used the terms drivers of change in small-scale fisheries.



Source: Allison et al. (2006)

Figure 2.1: Dimension of Poverty in Small-Scale Fisheries and the Framework to Address It

The external drivers are those related to international trade and globalization, markets, technology, climate and environment, demography, governance, etc. Fishery systems vulnerable to particular drivers which might vary across the fishery system and region because of system exposure, degree of sensitivity to the driver and adaptive capacity of the impacted groups (Hall, 2011). For example, fishers are highly expose to climate change and variability (floods, water level fluctuation, decreasing fish catch) while fishers are highly dependent on fishing as their livelihood portfolio (high sensitivity). Furthermore, fishers have limited access to other income activities due to lack of assets. Hence they have low adaptive capacity (FAO-SFLP, 2006; Hall, 2011). The concept of vulnerability could be an important starting point for poverty alleviation in rural livelihood because it deals with the impoverishment process of the vulnerable group. The human rights council of the United Nations (2012) has identified at least four main vulnerable groups working in the rural areas, namely smallholder farmers, landless people working as agricultural laborers or tenant farmers, small-scale fishers and the peasant women. It has also been used in development programs and frameworks such in the sustainable livelihood programs.

The second concept presented in the framework of Allison et al (2006) is marginalization, which also means social exclusion. Generally marginalization is the condition in which certain groups are discriminated against because of their race, ethnicity, religion, caste, gender, disability, etc (Atkinson, 1998). The root cause of poverty in small-scale fisheries is not because of their low productivity. Rather, it is due to the marginalization of this sector in the wider socio-political and institutional context (Bene, 2003; Bene & Friend, 2011; Pauly, 1997; Thorpe et al., 2005). Furthermore, it is scattered and are hence not very well recognized. Most of their products are not commercialized (Bene et al., 2009) due to limited skills and knowledge about commercialization, lack of access to information and credit as startup capital to develop small fishing enterprises (Isaacs, 2006). Pauly (1997) used the term of changing “mental maps” in order to reduce marginalization of the fishers by promoting new governance that perceive fisheries as an important sector, to use political will towards the development of fisheries communities and the changing gender roles. Inclusion of vulnerability and marginalization in the poverty framework of small-scale fishers has proven that poverty in this sector is complex and relates to a wide range of factors other than merely income (Bene & Friend, 2011). Therefore, poverty alleviation should embrace other factors outside fishing productivity such as ensuring access, control to the fisheries resources, better access to public services and infrastructure, decision-making processes over resource management, labour, markets, and access to credit because those factors have more impact on their livelihoods (Bene & Friend, 2011). Furthermore, poverty particularly in fisheries should be perceived from multiple dimensions, involving different stakeholders, and not only encourage production increases but also solid institutions facilitating the interaction of all stakeholders (Bene, 2003). Understanding the diversity of the fishing sector in relation to fishers' livelihood is a way of revealing the complex issue of poverty in small-scale fisheries (Bene & Friend, 2011). In line with that, poverty alleviation should be based on the value of fishing for the fishers including what fishing means to the fishers, the identity and satisfaction they get from fishing, hence allowing fishers the freedom to make sustainable decisions for their own lives and resources (Onyango, 2011a).

2.3 Fisheries decline, overfishing and fishing efficiency

There are many causes of overfishing particularly in inland waters, including the open-access of fisheries resources and individual profit maximizing of the fishers. The extinction of particular fish species is the indication of overexploitation in inland waters. This condition is defined as biodiversity crisis instead of fisheries crisis which means that overexploitation occurs when a particular fish stock has diminished even if overall fish production has increased (Allan et al., 2005).

Various reasons attributed to the cause overfishing from different perspectives. Cinner and McClanahan (2006) categorized exogenous and endogenous causes of overfishing in small-scale fisheries. Exogenous factors include market conditions while endogenous factors include pressures over fish resources that affect fish catch (Cinner & McClanahan, 2006). Pauly (1997) introduce the concept of malthusian overfishing. It is the increasing number of fishers due to new entrants who choose to do fishing because of lack of assets. Malthusian overfishing is defined as:

> "…what happen when these new fishers, who lack the land-based livelihood of traditional fishers (e.g., a small plot of land or seasonal work on nearby farms or plantations), are faced with declining catches and induce wholesale resource destruction in order to meet their immediate needs" (Pauly, 1997)

According to Malthusian theory, overfishing occurs when the fish resources reach the limit of its ability to naturally reproduce, accompanied by the increasing number of fishers and they have to continue fishing although confronted with declining catches. The symptoms of Malthusian overfishing include the increasing number of fishers leading to decreasing catch. This condition leads to biological overfishing (decreasing growth and recruitment success), when the value of fishing keeps decreasing while operational costs keep increasing (Pauly, 1997; Ssentongo, 1989). Such as in the case of African Lakes, some fish stocks species show symptoms of overfishing which is caused by increasing fishing efforts instead of increasing fishers number (Ssentongo, 1989).

Fish resources are over-exploited in many parts of Southeast Asia (Sievanen et al., 2005; Stobutzki et al., 2006), where excess effort and over capacity are among the main causes of resource decline. Managing over capacity in small-scale fisheries is more complex than in industrial fisheries due to high dependency on the resource either for food or livelihood, difficulties in enforcing regulations, seasonality, conflicting policies as well as lack of data availability (Pomeroy, 2012). Learning from experience in managing over capacity, a focus on people and community-related solutions is required (Pomeroy, 2012) through an integrated approach of resource conservation, livelihood improvements and restructured governance. Akpalu (2011) studied the link between efficiency (or skills) of the fishers and the degree of compliance to fishing regulations in the context of developing countries. It is found that less efficient fishers tend to violate rules and regulations, particularly those fishers with higher discount rates (the poor fishers). Therefore, livelihood improvement is suggested as one way to decrease violations of fishing regulations.

2.4 Livelihood diversification in fishing communities

Income diversification has been practiced in many rural poor communities to cope with poverty and income variability. Promoting income alternatives has been suggested by several studies on rural areas and poverty (Pittaluga et al., 2003). Rural households try to find other alternatives income sources and earn money from other activities because their current income sources getting decrease due to some factors including environmental changes. In order to sustain or enhance their livelihoods, most rural communities diversify their income. They earn money not only from one source of income such as agriculture but also from others such as collecting non timber forest products and fishing or vice versa. Livelihoods diversification is a way for rural households to cope with changes in a way that enables them to survive and enhance their livelihoods (Ellis, 1998). “Self insurance” is a term that is used to describe livelihoods diversification by which people try to deal with income variability and select other activities (Reardon et al., 1992; Reardon et al., 2000). Promoting alternative income generating activities for fishing communities attracts more labour, yields higher levels of mobility and security against uncertainty of the market and resource fluctuation (Panayotou, 1982).

People diversify their livelihoods due to different motives that can be categorized into necessity and choice (Ellis, 1998). Households tend to diversify their livelihoods in response to the crisis (Davies, 1996) or as the strategy chosen given particular conditions (Stark, 1991). Necessity reasons (involuntary) are associated with risk reduction such as limited land resource and resource degradation. Choice factors (voluntary) are those activities that complement the existing source of income or activities such as integration of crops and livestock, finding seasonal labour opportunities, investing money in other business (i.e trading or other business out of the current income source).

Rural communities are characterized by heterogeneity and various livelihoods strategies. The difference of socio-economic status indicates different livelihood strategies of particular communities (Ashley & Carney, 1999; Ellis, 1999). Different livelihood strategies are influenced by many factors including not only environmental conditions but also cultural, social and political background. Therefore, the reasons behind livelihood diversification and the impact it might have are different across assets, income, opportunity and social relations embedded in a particular location (Ellis, 1998). Most fishing communities in Ghana have very few assets such as land, therefore they tend to find other livelihood opportunities as labor and micro enterprises (Gordon & Pulis, 2010). Small-scale fishers are constrained by the lack of geographical mobility and lack of access to alternative employment activities which potentially increase the level of fishing efforts (Panayotou, 1982). Poorer households have less diversified incomes due to a lack of capital, hence they have fewer opportunities for other livelihood options (Abdulai & CroleRees, 2001).

Like in many other small-scale fishing communities, fishers in Malawi dealing with catch fluctuation in two different ways depend on the types of fishers. Specialist fishers were highly mobile while other fishers (settled lakeshore villagers) were surviving by income diversification both in farming and non-farming activities (Allison et al., 2002). Those strategies were also commonly practiced in fishing communities in Java, Indonesia; specialist fishers spread along the coasts and moving between islands depend on fish stocks and the local market. While in another part of Java, livelihood diversification is prevalent among the crews and boat owners.

Livelihood diversification is also commonly practiced among small-scale fishers particularly in Asia and Africa. They are also engaged in other income generating activities, so they are not considered full-time fishers (Bene & Friend, 2011). For instance, fishing communities in Lake Chad had been able to cope with fish catch fluctuation (in drought persistent inland fisheries) through diversification into farming. However, other livelihood options could not replace the role of fishing (including fish processing and trading) for household income where fishing still makes up the largest part of household revenue (Bene & Obirih-Opareh, 2009; Sarch & Allison, 2001). Another study found that the livelihood of inland fishing communities in Lake Chad is dependent upon three other main subsistence income activities, namely farming, livestock rearing wage-labor and migration (Bene & Friend, 2011; Bene, Neiland, et al., 2003).

In Southeast Asian countries where fishing is mostly a tradition, fishing is not only for economic but also non-economic reasons. A study of small-scale fishers in three Southeast Asian countries by Pollnac (2001) indicates various reasons fishers continue to survive amidst declining resources. Fishers from the Philippines fish to obtain food and income while in Maluku (Indonesia), fishing is considered an enjoyable occupation as well as a way to earn money for the family. The theory that alternative livelihood strategies and/or diversification could reduce pressure on fish resources might be successfully conducted/tested in some areas. Alternative occupations did not immediately reduce fishing efforts hence fish resource extraction (Hill et al., 2012; Pomeroy et al., 2009; Sievanen et al., 2005). Fishers tend to leave their new livelihood options and continue fishing (Pomeroy et al., 2009). Several studies have indicated that such management options would need an understanding of the socio-economic contexts in which fishers operate (Cinner et al., 2009; Hill et al., 2012; Pomeroy et al., 2009).

2.5 Households' typology and small-scale fisheries

In the context of great diversity of small scale fisheries and various stand-alone concepts of fisheries management proposed by previous studies such as institutional analysis, ecosystem approach, and many others, developing typology is considered a way to connect all the concepts and tools to formulate a management plan (Andrew et al., 2007). Developing typology in the fisheries sector would describe the characteristics of fishing activities and livelihood of its dependants and provide important information for appropriate management in addressing various types of fishing and its dependants. It is also a means to describe and explain the diversity of households. There has been lots of work on typology and characterization of small-scale fishers as an effort to make them recognized by policy makers for appropriate management measures. Brinson et al (2009) used socio-economic performance indicators and found that these indicators are effective to elucidate variety between the fleets in different locations and fishing objectives. Characterization of small-scale fisheries, their fishing activities and the socio-economic aspects in Mediterranean Sea was conducted as the significant factors to take into account in policy formulation (Battaglia et al., 2010). Guillemot et al (2009) characterized fishing activities in New Caledonia by developing a typology of fishing activities based on annual fishing effort, catch, yield and types of main gear used. The typology of fishermen in Greece was started by identifying the different fishing regions, most important gears used, and targeted species (Tzanatos et al., 2005). It is found that profiling the social and financial status of fishermen plays an important role in the formulation of a socio-economic understanding of fisheries management.

Development of typology as an approach to study the small-scale fisheries sector has been proven an important step in conflict management (Bennett et al., 2001) and it can explain the nature of the conflict (Charles, 1992). Studies on fishers characterization were not only based on socio-economic and biophysical factor but also institutional aspects as developed by Bene (2003). The typology was constructed to explain socio-institutional mechanisms as a new paradigm within the nexus of fisheries and poverty. Four different socio-institutional mechanisms were identified based on the factors that restrained them to fisheries resource. Furthermore, this type of typology can also be applied to other types of resource dependants. Sen and Nielsen (1996) used typology analysis to classify different arrangements of co-management in artisanal, semi-industrial and industrial fisheries in developed and developing countries. The study found key factors that determine co-management practices, namely types of boundaries, heterogeneity of user groups and the political and social background of the country.

2.6 Theories and principles on livelihood dynamics

Research published by Ellis and colleagues (Ellis, 1998, 1999; Ellis, 2000; Ellis & Bahiigwa, 2003; Ellis et al., 2003; Ellis & Mdoe, 2003) concurs on the fact that rural households with natural resources-based livelihoods in developing countries develop complex, dynamic and diverse livelihood systems, mostly as an attempt to reduce vulnerability (to risks and to uncertainty) and drudgery, and to maximize profit and increase food security. Besides structural diversity imposed by external environmental factors, rural households are developing contrasted livelihood strategies, developed on the basis of internal factors (e.g. household demography and labor force, choices and preferences, experience, capital accrued) (Abdulai & CroleRees, 2001; Barrett et al., 2000; Bene et al., 2000; Brugère et al., 2008; Chambers & Conway, 1991; Ellis, 2000; IMM et al., 2005; Reardon et al., 2006). Moreover, patterns of rural livelihood strategies, particularly in developing countries, is discerned across rural households by the diverse portfolio of activities for survival strategies (Barrett et al., 2001; Perret et al., 2005; Reardon, 1997). Better-off households have more livelihood options (Chambers & Conway, 1991) which might influence diversification patterns of the households, while the poor households show less access to capital assets (Mahdi et al., 2009) and less capacity to access livelihood opportunities (Barrett et al., 2001; Ellis, 2000). SSIF make no exception, and are associated with complexity and diversity in practices, performances, and livelihoods, particularly in developing countries, as shown by recent research (Bene et al., 2000; Berkes, 2003; Brugère et al., 2008; Guillemot et al., 2009; Tzanatos et al., 2005; Tzanatos et al., 2006; Ulrich & Andersen, 2004). Geheb and Binns (1997) have demonstrated the actual diversity, dynamics and complexity of fishing communities in East Africa (Victoria Lake), and highlighted various fishing-farming combined livelihood options, as strategies to cope with severe pressure due to a variety of economic and ecological factors associated with over-fishing and a significant decline in fish species.

Different strategies and responses to resource fluctuation at the individual, household and community level are observed. Transformations to alternative livelihood options and fishing practices (e.g. income diversification towards farming and off-farm activities), intensification (less factors used for same output, productivity increases) or (over)capitalization of fishing activities (increasing efforts, alternative fishing technologies) are commonly employed, prompted by diverse socio-economic backgrounds and the external institutional environment (Robards & Greenberg, 2007; Smith et al., 2005). While such dynamics are often not appropriately addressed in policy measures (Salas et al., 2007), transformations remain also ill-documented and analyzed in developing contexts (Smith et al., 2005).

Knudsen et al. (2000) define sustainability in fisheries as "*the long term viability and productivity of aquatic ecosystems, natural population diversity, and biomass that support healthy aboriginal, sport, and commercial fisheries and vital communities… for generations to come"*. Robards and Greenberg (2007) warn that "*…utopian resource management solutions that maximize or merely sustain all ecological, social, economic and legal components* [of a social-ecological systems such as inland fisheries] *are rare…*" In other words, all-dimension sustainability, as defined by Knudsen et al. (2000) can hardly be achieved: there are inescapable tradeoffs. Transformations in livelihood strategies and, more importantly perhaps, in fishing practices, seeking sustained catches and income, may lead to further losses in resource-based and ecological integrity.

2.7 Measuring technical efficiency in fisheries by using non-parametric approach, Data Envelopment Analysis (DEA)

Measuring technical efficiency in fisheries is recently attract more interests of scientist. Technical analysis is important because, in search of improved livelihoods, fishers tend to increase fishing efforts in order to increase catches, leading to further resource depletion and higher costs. High fishing performances (catches) are often not sustainable in the long-run and contribute more to resource degradation than more resource-efficient fishing systems. Technical efficiency in fishery is the measure of fishing fleets' ability to maximize outputs while minimizing inputs (fishing effort). Although capacity and efficiency have been widely investigated in marine fisheries research (Hoff, 2007; Kirkley et al., 2002; Kirkley et al., 2003; Madau et al., 2009; Maravelias & Tsitsika, 2008; Pascoe & Mardle, 2003; Tingley et al., 2005; Vázquez-Rowe et al., 2010; Vestergaard et al., 2003), the approach is still new in inland fisheries, with limited research done in developing countries (Esmaeili & Omrani, 2007; Pascoe, 2007). Thus discussion of DEA implementation would also include application in develop countries.

Although small-scale fisheries is mostly found in developing countries, there are very limited number of technical efficiency analysis comparing to fisheries biological aspects. Technical efficiency measures in fisheries is an important input for policy recommendation. The increasing technical efficiency would also increase the production growth with minimizing production costs (inputs variable). This condition would lead to three pillars of sustainability namely reducing poverty, minimizing pressures to the resources and an improved income distribution (Sesabo & Tol, 2007). Technical efficiency study of trawl fleet in Penang conclude that the fishers is facing the inefficiency problem which is caused by echo sounder (Ghee-thean et al., 2012). Therefore, the fishers should install echo sounder to increase their efficiency through the support from governments by providing loans or subsidies. From a methodological point of view, this study applied both stochastic frontier approach and data envelopment analysis and provided consistent results. Similarly, technical efficiency of fishery in Hamoon Lake was low and it is suggested that the fishers can improve their efficiency by using more inputs (Esmaeili & Omrani, 2007). The fishers in this lake use same technology, determinant of inefficiency is the skipper skills; those participate in training and better financial condition perform higher efficiency level. On the contrary, efficiency study in Mediterranean sea suggest that the fishers in this area should use their technical resources more efficiently to decrease their overcapacity practices thus increase revenues (Madau et al., 2009). Efficiency analysis of inshore fisheries in Kuala Trengganu, Malaysia revealed that the fishers still operate far from efficiency level therefore there is a slot for improving their efficiency through training and application of advanced technology (Aisyah et al., 2011). The efficiency estimation studies have provided information to policy makers and managers from different perspective. Increasing technical efficiency not only reduced poverty but also pressures to fish resources. Some previous studies have come up with various suggestion to improve efficiency which highly influenced by characteristics of the particular fisheries and the source of inefficiency.

2.8 Management of small-scale fisheries: issues, concepts and experiences

Small-scale fisheries play an important role particularly in the livelihood of poor people (providing foods and job opportunities), therefore assessment and management of this sector is a critical issue for the sustainability of resources and livelihood of its dependants. There is no clear definition of fisheries management. However, FAO defines fisheries management - in the technical guidelines for responsible fisheries as:

> *"The integrated process of information gathering, analysis, planning, consultation, decision-making, allocation of resources and formulation and implementation, with enforcement as necessary, of regulations or rules which govern fisheries activities in order to ensure the continued productivity of the resources and accomplishment of other fisheries objectives" (FAO, 2003a)*

This definition reveals that fisheries management covers multiple tasks consisting of fishery management authority and interested parties (Cochrane, 2002). Fishers and fishing communities are part of interested parties. Management authority is commonly an institution under government fisheries agencies at the national, regional and local levels. During the recent meeting of Rio+20 United Nations conference on sustainable development, a renewed commitment was made to put more attention on the management of small-scale and artisanal fisheries, particularly in developing countries for sustainable fisheries management.

Among the major identified problems within this sector is high dependency on fisheries resources, leading to over exploitation resulted in annual catch reduction. This condition is getting worse because of other external factors such as market price fluctuation, limited access to credit facilities, and lack of improved knowledge and facilities for fish processing and preservation (Chowdhury et al., 2011). Unclearly defined access and ownership over fisheries have led to the tragedy of the commons which is one of the many other reasons behind the failure of fisheries management (Allison, 2001).

A number of approaches and methods for alternative management have been increasingly developed during past decades including collaborative approaches involving resource users in the decision-making process and fisheries management, community-based fisheries management and co-management (Berkes et al., 2001; Chowdhury et al., 2011; McClanahan et al., 2009), incentive-based approach which better stipulates the harvesting and territorial rights of individuals and groups (Grafton et al., 2006; McClanahan et al., 2009), taking into account uncertainty and complexity considering fisheries as complex adaptive systems and socio-ecological processes that can be reflected through livelihood issues, community-based institutions and cross-scale governance (Berkes, 2003; McClanahan et al., 2009). Onyango (2011b) outlines some important changes to be implemented for an improved poverty alleviation program in small-scale fisheries including changing the perception about poverty itself from a natural phenomenon into governance issues. For that, the government should consider fishers as the partner and come up with genuine solutions from the particular fishing communities.

In order to prevent further decrease of fisheries resources and problems associated with small-scale fisheries in Southeast Asia, improved management involving resource users and local communities is urgently needed. The idea of active participation of resource users actually has been part of the development process in Southeast Asia since 1960 but it was not well reflected in the policies and resource management. Therefore, it failed to accommodate resource users leading to conflict over resource use and resource depletion (Pomeroy, 1995). In view of this situation, community-based and co-management must be implemented through legal, administrative and institutional arrangements at every level of governance (Pomeroy, 1995). Pomeroy (2001) has identified several factors that contribute to the success of fisheries co-management in the context of Asian countries. Those factors are grouped into three levels based on the classification system created by Pomeroy et al. (1996) namely supra-community level, community level, and individual and households level. Supra-community level refers to external factors such as supportive government institutions; conditions at community level affecting the success of co-management include physical and social environment such as participation, leadership and empowerment; individual level is the key factor for the success of co-management and therefore the creation of incentive structures is an important condition for individuals to participate in the co-management process (Pomeroy et al., 2001). Community based fisheries management system has long time exist around the globe both in develop and developing countries. However, it is poorly documented including for Indonesian fisheries which is well-known by its diverse fisheries tradition The existence of community fisheries management in Asia-pacific intensively discussed by Ruddle (1994). The major issues of community based fisheries management in the Asia-Pacific regions are undocumented information in terms of types, functions and statuses of its system, also lack of data on ecological, general fisheries and socio-economic setting (Ruddle, 1994).

In addition to the above approaches, Andrew and Evans (2009) introduce three types of management implementation frameworks of small-scale fisheries in the developing world, namely an ecosystem approach to fisheries (EAF), stakeholder's rights-based approach and co-management and resilience management approach. The aim of the proposed framework is to bridge the gap in conventional fisheries management (i.e focusing on the maximum sustainable yield, single species management approach). These frameworks can work together to contribute to a more holistic fisheries management and governance system. Such integration of EAF and resilience frameworks has greatly improved the management in this sector.

Ecosystem-based fisheries management has emerged during the last decade. Many definitions of this approach have emerged. "Ecosystem based fisheries management (EBFM) recognizes the physical, biological, economic and social interactions among the affected components of the ecosystem and attempts to manage fisheries to achieve a stipulated spectrum of societal goals, some of which may be in competition" (Marasco et al., 2007). The ecosystem approach for fisheries management "strives to balance diverse societal objectives by taking into account the knowledge and uncertainties about biotic, abiotic, and human components of ecosystems and their interactions and applying an integrated approach to fisheries within ecologically meaningful boundaries" (FAO, 2003a). Despite some of its challenges, this approach has been widely implemented and has shown that the ecosystem approach has improved fisheries management for ecosystems and multiple jurisdictions in the Philippines (Pomeroy et al., 2010). The ecosystem-based approach is considered the appropriate management tool for the degraded fisheries resources due to pressures in inland fisheries (hydropower, waste disposal, pollution, water needs for many daily activities). However, the ecosystem approach should be accompanied by a participatory approach because the ecosystem-based approach has not always been successfully implemented for the case of European inland fisheries (Cowx & Gerdeaux, 2004). Hence, the approach should be accompanied by active participation from all stakeholders in the decision-making process, management and post-project monitoring. The ecosystem-based approach could be an appropriate management tool for small-scale fisheries in particular for developing countries because it incorporates the complex ecosystem, which is a fitting model for fisheries in most developing countries. However, the implementation of the ecosystem-based approach should take into account various factors such as scales of operation, and the effect of fishing on fish stocks, other habitats and species (Mathew, 2003). All of these are difficult tasks and very costly especially for developing countries though it is still feasible with assistance from international agencies. Fisheries mismanagement occurs as the result of adopting fisheries management from particular area to others such as adoption of western fisheries management into tropical countries. The characteristics of both area is greatly different, hence the management objective is also different (Ruddle & Hickey, 2008). Furthermore, fisheries management of western countries focus on fish stocks and its externalities while the tropic countries should put more attention on stock externalities, gear externalities and competition to resource access.

Technical problems and constraints in fisheries management and conservation practices of inland fisheries in Indonesia include the lack of understanding of techniques of conservation at both community level and policy makers; limited availability of local species stock; lack of clarity of implementation strategies due to insufficient scientific data and information; the absence of impact analysis, motoring, evaluation and controlling of the fisheries enhancement programs; unclearly defined property right systems;

management institutions as one unit under co-management has not yet established (Weimin et al., 2010). Conservation initiatives were mostly conducted based on the project with much less attention to community participation. The managers should also understand how fishers respond to fish fluctuation because this will determine the shape of their livelihood instead of only focusing on maximum catch yields (Sarch & Allison, 2001). Another example of fisheries management failure is case of inland fisheries in Africa which highly influenced by climate change, while state-led fisheries management has failed to consider the significance of climate change upon fish fluctuation and how fishers' strategy to response and cope with this condition (Sarch & Allison, 2001).

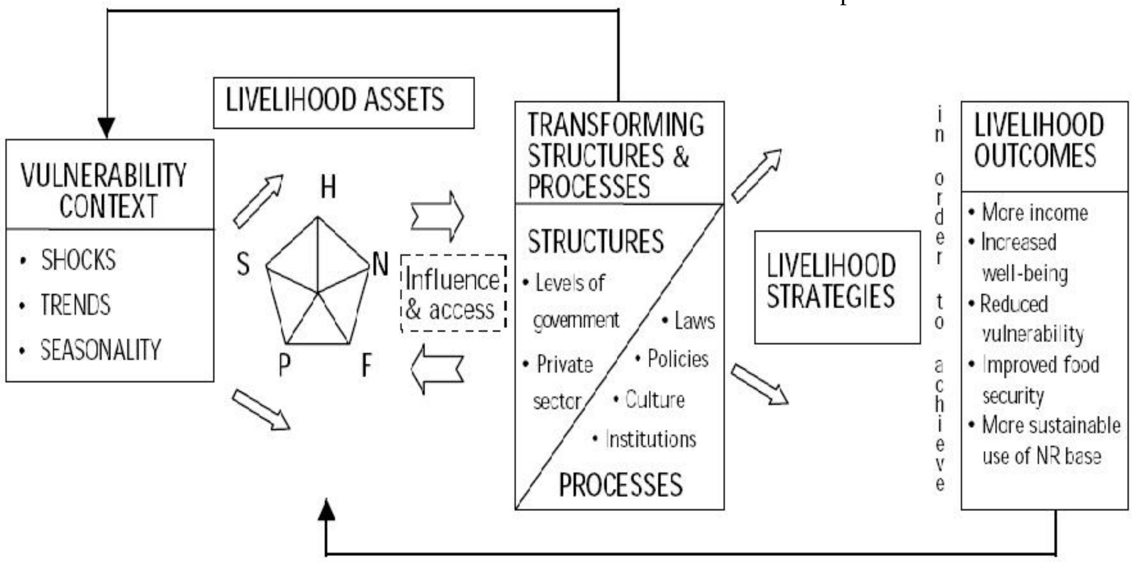
2.9 Livelihood analysis framework

Another widely implemented approach which links poverty and resources use is the sustainable livelihood approach. Sustainable livelihoods framework developed by DFID is one of many other agencies that also formulate their own livelihoods framework including CARE, Oxfam, and UNDP. The basic principle adopted by all of these agencies in developing this framework is the concept of sustainable livelihoods that was defined by Chambers and Conway in early 1990s. They defined sustainable livelihoods as follows: "a livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living: a livelihood is sustainable which can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels and in the long and short term" (Chambers & Conway, 1991). Basically, all frameworks adopt the same principle namely asset based approach. However, there is a different way of thought regarding sustainability among those frameworks. The agencies emphasize on different factor, for example CARE emphasize on livelihoods security at household level. One of the widely used livelihoods framework is sustainable livelihoods developed by DFID.

Sustainable livelihoods framework (Figure 2.2) that developed by DFID is aimed to eradicate poverty and increase livelihoods of the poor through improvement of access to education, information, better access to natural resources, infrastructure as well as financial resources. Sustainable livelihoods is also subject to the creation of supportive social environment, policy and institutional. The ability of SLF to incorporate socio-economic and technical aspect altogether is beneficial in livelihoods analyses. DFID framework comprised of six main principles in the implementation of poverty alleviation development project (Carney et al., 2000). The principles are people-centered, responsive and participatory, multi level, conducted in partnership, sustainable and dynamic. In addition, the framework also stresses the analysis of five capital assets and the outcomes. Outcomes is important indicator to know the impacts of development activities to people's livelihoods.

Vulnerability comprised of three main factors that influence people's livelihoods assets. Those factors are trends, shocks and seasonality. Shocks can occur from nature, human, economic factors such as floods, storm, drought, conflict or even the depletion of crops or livestock's health. Trends also influence livelihoods assets although it might not have direct effect since it is more predictable, for example population growth, governance and technological trends. Seasonality can be in the form of changes of price, production, and fluctuation of fish stocks in fisheries sector. Vulnerability context does not always have negative impact upon people's livelihoods. Moreover, vulnerability is able to help people to become more resilience when it is accompanied by support such as financial and institutional (DFID, 1999).

Key:
H=human capital S=social capital
N=natural capital P=physical capital
F=financial capital



Source: DFID (1999)

Figure 2.2: Sustainable Livelihood Framework

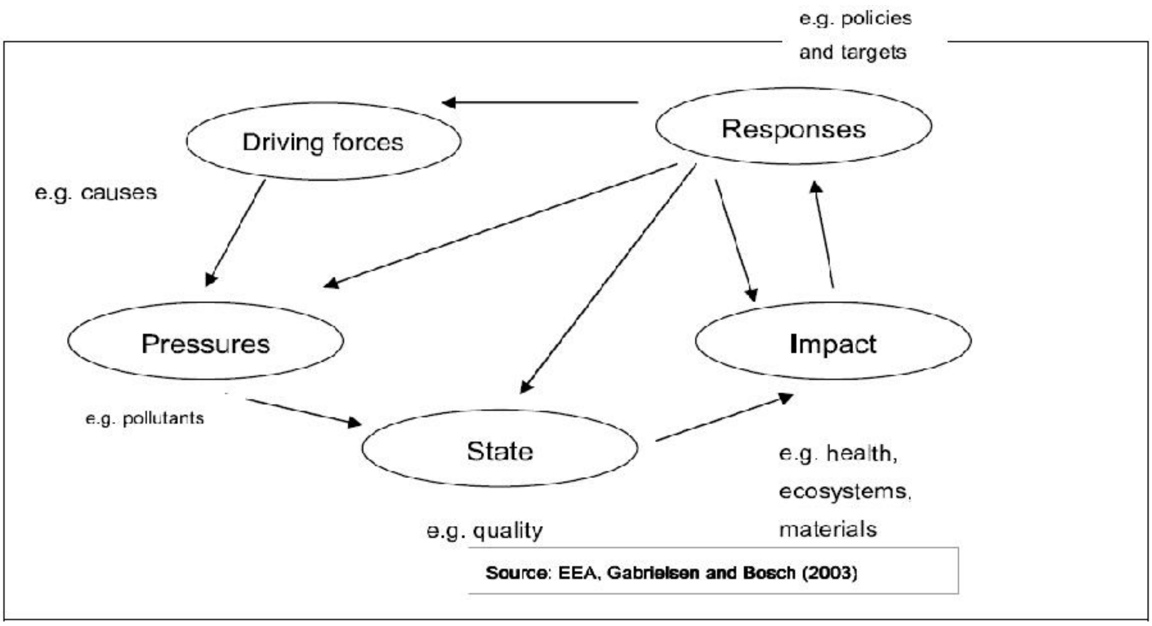
The status of livelihoods assets would determine the livelihoods strategy adopted by the people to sustain or increase their livelihoods due to vulnerability. Shocks, trends or seasonality pattern in particular time and area would influence the condition of the five livelihoods assets dimension differently. There are five livelihood assets (asset pentagon) which is the core of the livelihood framework. Human capital (skills, knowledge, education, health); social capital (social networks and connectedness, membership in an organization or more formalized groups); natural capital (fish resource, land, forests); physical capital (affordable transportation, secure settlement, adequate water supply and sanitation, access to information and communications); and financial capital (savings and regular inflows of money such as pension and remittances). The five asset pentagon is connected each other, one physical asset might generate other assets or benefits (DFID, 1999). For example, having access to natural capital such as land, people might also have strong financial capital because they can earn income from land cultivation and they would be able to get loans through land asset as the guarantee.

The sustainable livelihood approach by DFID (1999) has brought insights into management planning and policy formulation. This approach has been widely implemented for managing small-scale fisheries particularly in developing countries (Ahmed et al., 2008; Allison & Ellis, 2001; Allison et al., 2002; Allison & Horemans, 2006). Sustainable fisheries management supports small-scale fishers to increase their capacity to encounter poverty by maximizing the use of their existing capital and capabilities (Allison & Ellis, 2001). Hence, the sustainable livelihood approach (SLA) has identified factors contributing to poverty alleviation in the fisheries by focusing on existing resources instead of putting more pressure on fisheries resources.

2.10 Drivers, pressures, states, impacts and responses (DPSIR) framework

Environment is likely to change over time due to development and population growth. The assessment of environmental changes affected by human activities must be conducted comprehensively by integrating all factors including social, ecological and economic. Understanding the interaction within related factors and the changes of environment become a complex problem. Therefore, choosing appropriate set of indicators is very important to describe cause effect relationship among ecological, economic, social interaction (Giupponi et al., 2004) and better understanding on the dynamics environment can be achieved as the information source for decision makers, stakeholders.

Pressure – state – response (PSR) framework developed by OECD and DPSIR framework initiated by Environmental Agency and Eurostat (Gabrielsen & Bosch, 2003) are among the suitable approach to assess environment and its changes due to human activities. The frameworks have sets of indicator that could further analyze the cause effect relationships of environmental changes. The frameworks take into account the interaction of social, economic and environmental aspect (Giupponi et al., 2004). PSR framework shows the linear relationship where the pressures on the environment cause the changes, and then measurement of changes with some indicators is presented as the state of environment. The response arises from the pressures and state of environment as the reaction to environmental condition. It describes that PSR framework does not fully capture the dynamic interaction among social, economic and environmental factors. DPSIR framework was then developed which is basically similar with PSR framework. However, DPSIR has two additional indicators namely driving force and impact indicators. Driving force resulted from people's behavior associated with economic pressures and what are the impacts to environment and people's livelihoods due to the environmental changes.



Source: Gabrielsen and Bosch (2003)

Figure 2.3: DPSIR Framework

Therefore, DPSIR framework provides more comprehensive analysis on environmental changes by incorporating social, economic and environmental aspects. DPSIR framework comprised of five main components namely driving force, pressure, state, impact and response (Figure 2.3). The indicators for analyzing the complexity of environmental problems are groups into those five components.

Millennium ecosystem assessment reports use the term “driver” that is defined as the factors both natural and anthropogenic (human-induced) causing environmental changes (Nelson et al., 2005). The drivers might directly or indirectly affect the environment. Biological, chemical and physical processes are the factors that affect environment directly such as air pollution, land cover and land use changes. Indirect drivers include population growth, socio political and economy growth (Nelson et al., 2005). Driving force is associated with socio-economic factor leading to environmental changes either positively or negatively. On the other words, driving forces related to social, population and economic development that cause pressure to environment. Kristensen (2004) associated driving force with a need. Food, water, shelter, mobility and entertainment are human needs but at the same time all those needs create forces environmental changes. OECD describes pressure as “the changes of environment quality and the quantity of natural resources”. Such as decline of water quality due to pollution from industrial or agricultural activities, air pollution as the result of gas emissions from industrial and engines, the increase of critical land. Population growth contributes to the pressures because more people would demand more resources. Unsustainable use and limited availability of resources has led to greater pressure to environment and resources. The measurement of environmental condition is identified as the state of environment. In the context of environmental quality depletion, states of environment describe the concentrations of pollutants in particular resources such as water, air. The measurements of states are based on parameters specific to the degraded resources.

The changes of environmental condition impact upon human, animal and ecological condition as well. The impacts are interrelated, the changes on ecological condition affect the ability of resources to provide services to human and threatened biodiversity. Humans themselves are the driving force behind biodiversity changes (MEA, 2005). There is a feedback loop relationship between humanity and nature. From this relationship, it can be concluded that human activities cause environmental changes that affect its ability to provide ecosystem services, degradation of services impact human livelihoods. In order to cope with environmental changes, some strategies are adopted either by the politician, decision makers or local people at community level. At higher level, decision-makers or politicians might responses the changes by formulating policy or implementing program activities to deal with the changes. All the efforts adapted at every level (central, local or community) in correspond to environmental changes are considered as responses factor in DPSIR (Drivers-Pressures-States-Impacts-Responses) framework.

The DPSIR framework has been widely used as the analytical tool to study complex environmental issues and the impact to resources and the users. In fisheries sector, this approach has been able to investigate and model the driers and pressures over the environment and increasing fishing pressures (Knudsen et al., 2010; Mangi et al., 2007). One of the main limitation of DPSIR framework is the inability to address the impact of aggregated local response (Ness et al., 2007) which is the core issues in explaining human and nature relationship. Therefore, integration of DPSIR framework into sustainable livelihood have been implemented as the solution to overcome the limitations of the

DPSIR framework alone, to better understand human and environment relationship and bring new directions to development planning (Ness et al., 2007). Schrevel and Kumar (2010) applied the integrated framework of livelihood concept to DPSIR framework in wetlands ecosystem. They investigated livelihood profiles and practices and how they develop. While DPSIR framework is able to briefly map out the environmental issues and the impacts, livelihood analysis enables the analysis of the history of users' livelihood, and setting of the resource, ecosystem services being used and characteristics of the livelihood type (Schrevel & Kumar, 2010).

2.11 Overview of fisheries management in Singkarak lake

Fisheries management in Indonesia is under the government at the regency level while there is still a lack of understanding of and support to conservation of inland fisheries. In the case of Singkarak Lake, clear management and better-developed institutions are greatly required because the lake is located between two districts, namely Solok and Tanah Datar. The catchment area of the lake is located within four regions: Solok and Tanah Datar district, Padang Panjang and Solok city. Located across many districts, the management of Singkarak Lake involves many groups of stakeholders and users. Currently, the lake is managed by a steering committee at the provincial level. However, there has not been particular laws or regulations for the management of the lake and its catchment. Moreover, there is not any legal solution to solve the problems in Singkarak Lake (Farida et al., 2005).

Major problems in lake resources in Indonesia include water pollution, extinction of many important species, and habitat destruction due natural and artificial activities (Anshari et al., 2005). These problems are also found in Singkarak Lake which also impacts the livelihood of its dependants, particularly fishers. Learning from the experience of the Lake of Sentarum National Park, Anshari et al. (2005) identified major problems for each stakeholder such as lack of local capacity and the increasing population at the community level. While from the government side, the very lack of coordination and cooperation among the agencies and the local community puts more attention on project completion than on development goals. Hence, lake management in Indonesia should pay more attention to involving local communities and strengthening cooperation among the agencies such as the local community, various government agencies, non-governmental organizations, and private sector and international agencies. Poor participation from resource users (fishers) in decision-making and fishery management is believed to be one of the reasons of fisheries management failure (Allison, 2001).

Chapter 3

Research Design and Methodology

This chapter describes the methodologies employed to collect ecological and social data regarding the current condition of lake resource and livelihood strategies of small-scale fishers, fishing practices, households diversity and their efficiency in utilizing fishery resource. The methodology presented in this study consists of five components, namely, conceptual framework of the study, selection of study area, research design, data collection techniques and data analysis.

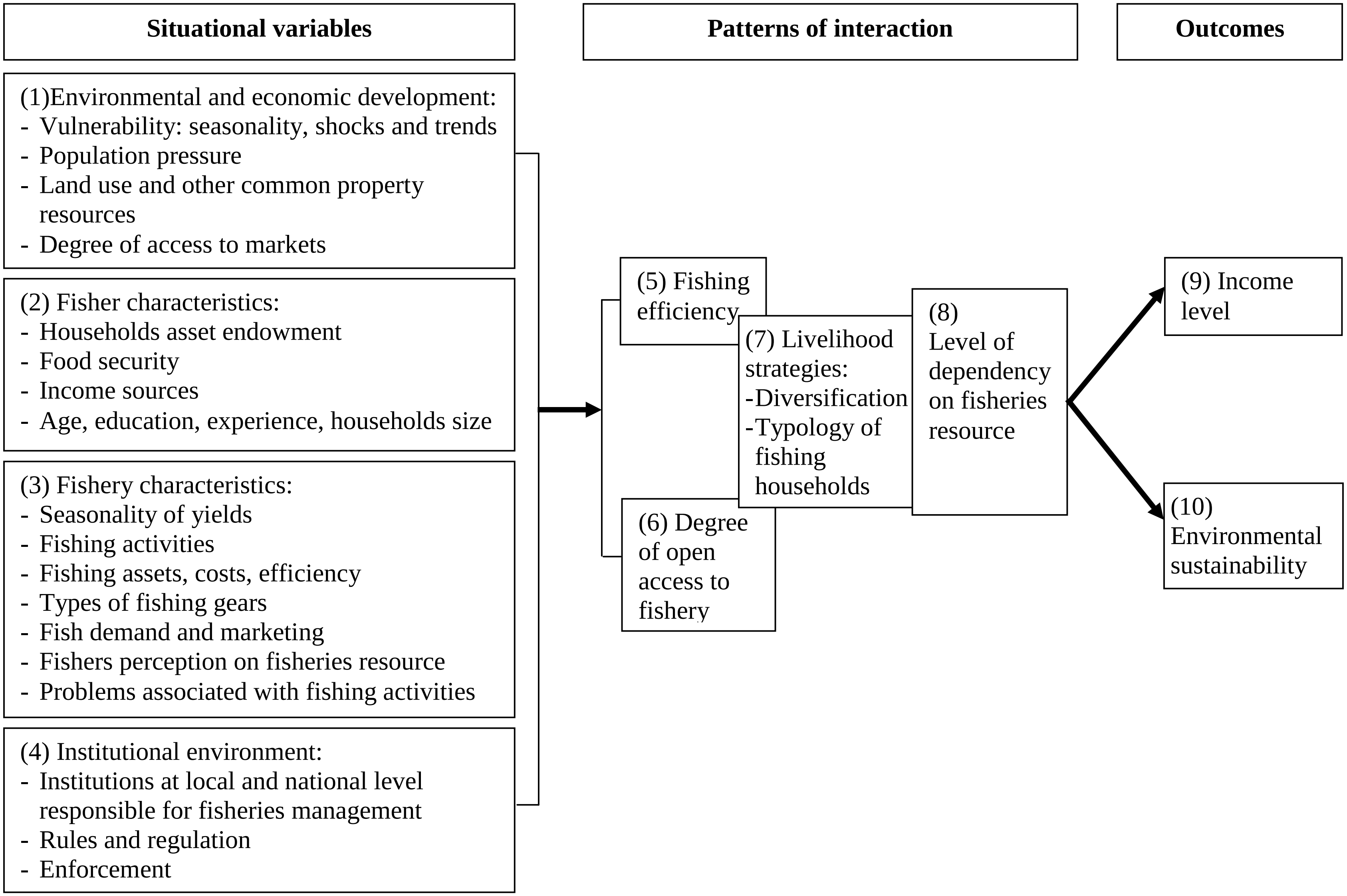
3.1 Conceptual framework

The starting point of the study is comprehensive assessment of the lake environmental issues, fisheries situation and identifying socio-economic issues by using DPSIR analytical framework. This framework mapped the complexity of environmental problem and the impacted parties. It focuses on the small-scale fishers livelihood as one of the impacted parties by the changing environmental and fish resource. Their livelihood strategy is analyzed by using modified sustainable livelihood framework for inland fisheries. The performance and efficiencies of fishing practice are measured by DEA as analyzing tool in order to further explain over capitalization practice and link with their livelihood strategies. Final conclusion presented with DPSIR framework with integration of results from livelihood analysis (diversification and fishing strategies).

In order to develop a management strategy for sustainable fisheries management under the current threat of exploitation and degradation, it is important to understand the nature of the fishers, their livelihoods and their socio-economic characteristics. This study uses the modified version of framework developed by Smith et al. (2005), which was designed on the basis of the framework for analyzing the commons propounded by Oakerson (1992), and analysis of sustainable rural livelihoods framework by Allison and Ellis (2001). Smith et al. (2005) developed a more comprehensive framework for inland fisheries explaining fishing activity and livelihood outcomes of the fishers.

Figure 3.1 provides detailed livelihood analysis of fishers within the context of physical, socio-economic and institutional attribute (Box 1 – 4). This framework enables the user to describe and better understand the livelihood of inland fishers. The framework consists of three main parts: 1) situational variables, assessment of four components, namely, environmental & economic development, fishers characteristics and the institutional environment, 2) pattern of interaction among those variables and its sub components, which was evaluated in terms of fishing efficiency, access to fisheries resource, livelihood strategies and the extent of fisher's dependence on fisheries resource, and 3) outcomes of interaction among the variables, which are are income level and sustainability of fisheries resource.

SSIF are associated with complexity and diversity in practices (Bene et al., 2000; Berkes, 2003; Brugère et al., 2008; Guillemot et al., 2009; Tzanatos et al., 2005; Tzanatos et al., 2006; Ulrich & Andersen, 2004) which influences the role of fishing as one of main livelihoods strategies, fishing efforts and their levels of dependence. Understanding technical attributes (Box 3) of fisheries and characteristics of fishers is very important to analyze patterns of operation and outcomes of resource use. Besides structural diversity imposed by external environmental factors (Box 1), rural households are developing dynamic livelihood strategies based on internal factors such as households demography and labor force, choices and preference (Barrett et al., 2000; Chambers & Conway, 1991; Ellis, 2000; Reardon et al., 2006). Internal factors that further describe fisher's characteristics (Box 2) were examined to evaluate diverse functions of fishing in rural households by developing fishing households' typology. Typology of households based on livelihood function of fishing will influence labor division, which then affect level of resource use and its outcomes (Box 8, 9 and 10).

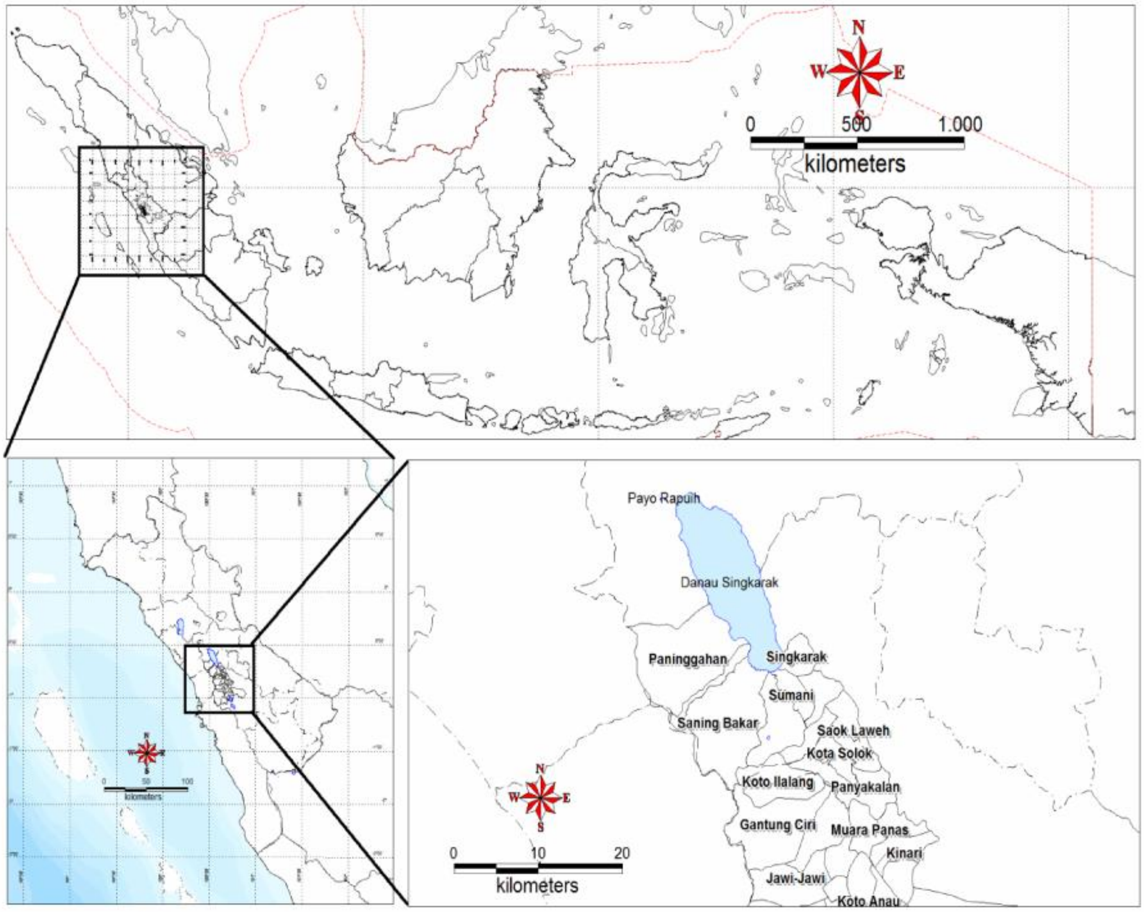


Source: modified from Smith et al (2005)

Figure 3.1: Conceptual Research Framework

3.2 Study area

Singkarak Lake is a large lake (13,665 Ha) 160 m deep, located in West Sumatra Province, Indonesia. The lake water and its shoreline area are shared between two districts; Tanah Datar and Solok (Figure 3.2). Five main rivers drain into Singkarak Lake, which form the inflow for the lake. They are Batang Malalo, Batang Ondoh, Batang Paninggahan, Batang Saniang Baka, Batang Sumpur and Batang Sumani. The lake is one of the important resources within this area, and is heavily utilized as the main water source for irrigation in the downstream districts areas; Tanah Datar, Padang Pariaman, Solok and Sawahlunto Sijunjung. Another main utilization of the lake water is for supplying water for hydroelectric power, called PLTA Singkarak.



Source: Modified from land use map produced by Department of Water Resource Management of West Sumatra

Figure 3.2: Map of Indonesia and Study Site Location

Singkarak Lake has been chosen as the study site for the following reasons:

1. Singkarak Lake is the largest lake in West Sumatra Province. The lake has a significant role in providing services for people living in this area and its surrounding. Despite its important role, Singkarak Lake is reported to be currently facing environmental problems and fish depletion, for which many explanations have been propounded. However, the livelihood of the fishers in this area has not garnered enough attention from government and managers. In most cases, panacea solution of fishery problem has certainly ignored the fishers' concerns and needs.

2. The area is experiencing rapid development activities such as infrastructure construction, including access road to villages surrounding the lake and hydro-electric power plant. Most of development activities potentially contribute to more severe degradation of the lake. Therefore, understanding the current condition of the lake will be important input for stakeholders and decision-makers for a better management options.

Singkarak Lake is surrounded by 17 villages called *nagari*[1]: Simawang Barat (Ombilin), Padang Luar Selatan, Tanjung Mutiara (Desa Batu Tebal), Sumpur, Padang Lawas, Malalo, Tanjung Sawah, Duo Koto, Guguak, Baing, Paninggahan, Saniang Baka, Singkarak, Tembok, Kacang, Batu Limbak and Simawang Tangah. Five of these nagari — Simawang Barat (Ombilin), Sumpur, Guguak Malalo, Paninggahan and Saniang Baka — are directly attached to Singkarak Lake. For the purpose of this study, four Nagari were selected; Saniang Baka, Paninggahan, Guguak Malalo and Sumpur. These nagari were selected because of their proximity with the Lake, and because most of the villagers are fishers or involved in fishing related activities. The four major influent rivers of the basin are located within the sampled nagari.

3.3 Research Design

Figure 3.3 shows research framework and how it was conducted in order to cover the objectives of the study, and address the research questions in context. It starts from selection of research topic based on the review from some documents supported by related theories and concepts. Reconnaissance survey was conducted prior to data collection. Ecological information of the lake resource was obtained from review of project reports, documents and statistics, key informant interviews and focus group discussion with fishers group. Key informant interviews and focus group discussion were also employed to gather data about livelihood strategy of fishing households. Household surveys were carried out in the third step of field data collection after gathering previous information from reconnaissance survey, key informant interviews and focus group discussion.

[1] *Nagari* is the name of the traditional village, pre-colonial political units of Minangkabau political organization (Benda-Beckmann, F. and K. von, 2001)

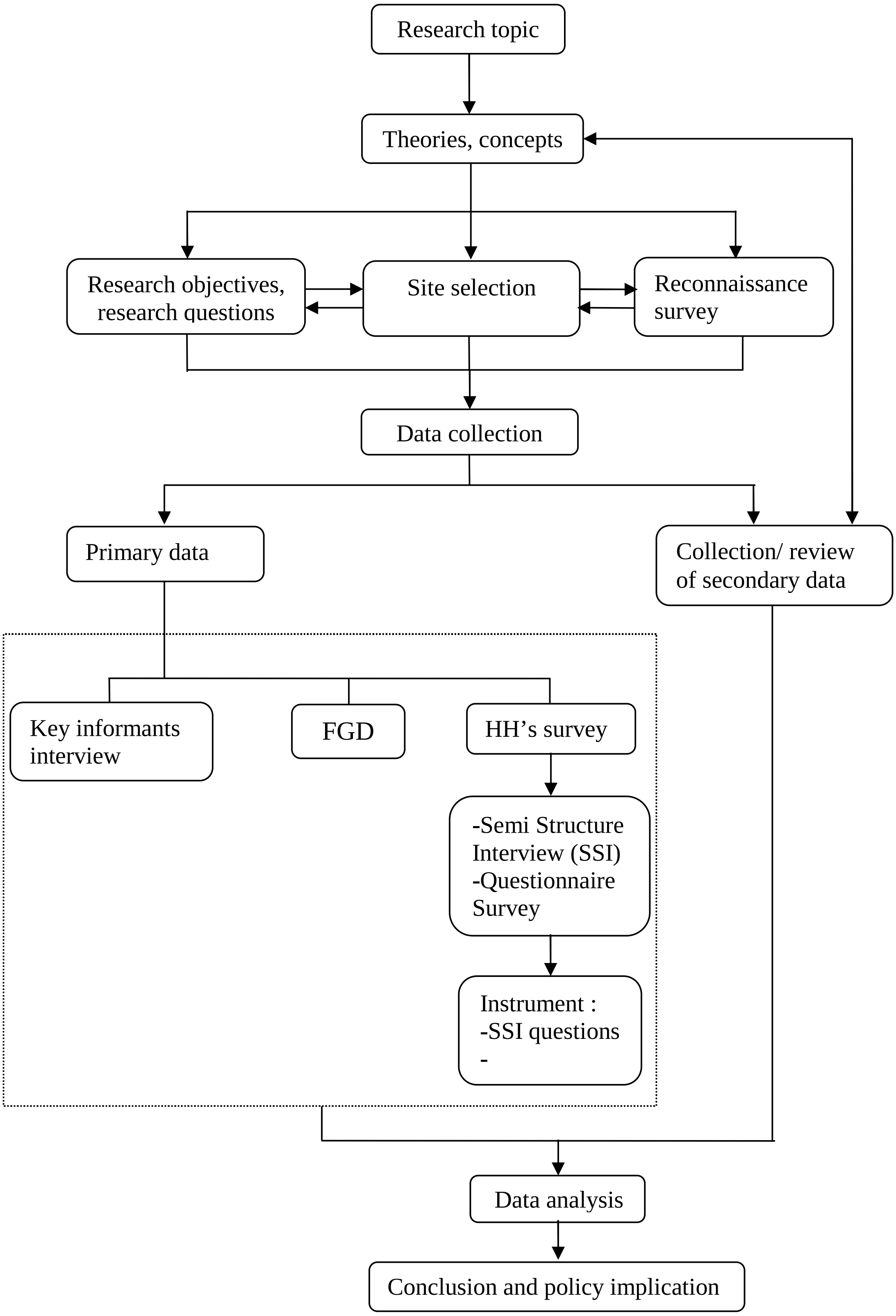


Figure 3.3: Research Design

3.4 Data Collection and Techniques

Data collection, including both primary and secondary data , was conducted from March 2009 – January 2010. Prior to data collection, reconnaissance survey was undertaken for about 3 weeks. Secondary data includes reviewing literatures in same topics of this research and some others related documents to give better understanding of the topic being studied. Primary data was collected through triangulation of some qualitative and quantitative techniques. First, semi-structured interview was carried out with key individuals (heads of Nagari, village elders, selected fishers, etc). Second, focus group discussions (FGD) was carried out with fishers and fishing households. Third, Household survey data was collected by using pre-tested semi-structured questionnaires. Combining qualitative and quantitative methods as a practical tool particularly in examining livelihoods diversity have been suggested from previous research (DFID, 2002; Ellis & Freeman, 2004).

3.4.1 Collection and Review of Secondary Data

Relevant secondary data from many sources were collected and reviewed in this study, which included journal articles, government documents such as socio-economic, demography, physical, biophysical, and climate data, case studies and project reports. Fisheries data (the amount of fish catch, prices variation during last ten years, etc.) was collected from provincial marine affairs and the Fisheries Department in order to know the current status of fisheries resource in the study area. Data on environmental aspect of the lake including water quality and lake level were obtained from the Provincial Government. In addition to socio-economic and biophysical data, secondary data mainly include:

- Fisheries resource information (stakeholders, institutions, production)
- Agricultural production information (including production, price of the product)
- Water quality data
- Lake water level
- Climate and hydrological data
- Land use

These data were used for guidance and cross-checking during primary data collection or field work.

3.4.2 Collection of Primary Data

3.4.2.1 Reconnaissance survey

Reconnaissance survey was conducted prior to data collection in October 2008. There were two main activities — A visit to the World Agro Forestry Center (ICRAF) office in Bogor, West Java, and a visit to the study area. ICRAF is one of the institutions that have conducted some research related to payment for environmental services. Discussion with some ICRAF researchers resulted in better understanding of the recent and concrete environmental problems in the study area. The discussion is also aimed to share ideas to avoid overlapping of the research. The next activity was visiting the study area to get familiar with biophysical, socio-economic as well as cultural environment in order to design the study. This activity included visits to some *nagaris*, some strategic sites of the lake affected by pollution, and tributaries areas to observe fishing activities. In addition, discussions with respected knowledgeable elders, head of *nagari Paninggahan* and its staff, and some local people were also conducted.

3.4.2.2 In-depth interview

In order to gather more detail about the current condition of lake environment, fisheries resource and fishing activity, interviews with some key informants from different background were conducted. Further, in-depth interviews were also performed as a tool to get information on the use and importance of lake resource to local people, rules and regulations regarding fishing practices, cultures, values and attitudes of the local people. Information on environmental issues related to water quality and quantity problem can also be gathered through this technique. Details of key informants and information collected are presented in Table 3.1.

Table 3.1: List of key informants

Key informants	Information
Head of *nagari*	General information on socio-economic, biophysical condition
Knowledgeable elders	Customary rules, regulation, trend of fishing activities
Local institution's staff	Implementation of customary rules, regulation
Agriculture officer	Farming system, land use
Fisheries officer	Fisheries resource and fishing activity
State electric company officer	Condition of the lake in terms of water quality and level of the lake, HEPP operation
Local environmental impact management agency officer	Environmental condition of the lake and its catchment area

3.4.2.3 Village survey

The information on *nagaris* surrounding Singkarak Lake was collected through village survey records such as *nagaris* demography, infrastructure, labor market condition, education and community assets, land type, main economic activities, proportion of land uses, access to resource, customary rules and regulations, any programs or project that have been conducted in the Singkarak Lake and its surrounding, mode of transportation and communication. The information was collected from the head of sub district, head of *nagari*, local institutions staff and other knowledgeable persons within *nagari*.

3.4.2.4 Focus Group Discussions (FGD)

Focus Group Discussions were carried out with fishing households' group. It was conducted in six Nagari, with an average 12 participants in each group. The discussion started with a brief presentation about the aims of the research and the topics for discussion. The fishers were encouraged to express their opinion and experience about relevant issues including:

- The importance of lake resource for local people
- Current condition of the lake resources, the changes noticed by the fishers and the reasons behind the changes
- Fishing activities
- Constraints and suggestion for fisheries management

3.4.2.5 Field observations

Observation is an important data collection technique to gain behavior in natural environment. through observation, the researcher obtains data on men's and women's workloads, fishers activities: what goes on, who involved, when and how they occur (Bailey, 1994; Jorgensen, 1989). Moreover, note-taking and information collected during observation are useful to enrich the interview list with key informants. Field observation conducted in this research covers both, the observation of surrounding environment and the people involved (fishers and farmers). Cultivation techniques and practices in the areas surrounding the lake, fishing activities, sewage system, waste management of households, hotels and restaurants surrounding the lake were observed during the fieldwork. We also attended a few random informal gathering of the farmers and fishers where they discussed about any issues concerned.

3.4.2.6 Household survey

Household survey was carried out by using structured questionnaires. A Detailed quantitative questionnaire was developed using the preliminary information gathered during the previous stages of data collection (in-depth interview, village survey, FGD and observations). After testing and adaptation the questionnaire was then used in household survey. The questions covered specific information on household structure, demography, livelihood, income, assets, fishing practices, characteristics and activities.

Sampling technique

The interview was conducted in the local language, face-to-face. Two hundred fishing households (covering a total population of 1220) were randomly selected in four sub-populations (selected Nagari).

3.5 Data Analysis

The data obtained from the survey questionnaires was coded and fed into SPSS (Statistical Package for Social Science). The data was summarized and analyzed by this program. This study used inferential statistics by considering parametric and non parametric statistics so that a more powerful analysis could be presented. Mathematical programming PIM – DEA software is specifically used to quantify technical fishing efficiency of the fishers.

3.5.1 Qualitative analysis

Qualitative analysis was used to analyze the results from in-depth interviews, FGD, observations and village survey. The data is presented in a descriptive report combined with statistical information, graphs and tables from quantitative analysis. The method was employed for exploring current condition of the lake resources and its environment, recording of respondents' perceptions on fisheries resources, and major concerns of the fishers.

3.5.2 Quantitative analysis

Household survey data was analyzed with SPSS. Descriptive and inferential statistics were applied for analyzing data. Characteristics of fishing activities and fisher's households in Singkarak Lake were analyzed by using descriptive statistics. Socio-economic and fishing data were analyzed to construct fishing household typology by using multivariate statistical techniques namely Principal Component Analysis (PCA) and Cluster Analysis (CA) in the SPSS package. Data Envelopment Analysis (DEA) was applied to the household survey data in order to show household efficiency in mobilizing inputs towards maximizing the outputs and to reveal possible trends of intensification or overcapitalization.

3.5.2.1 Perception and attitudes

Perceptions and attitudes of the fishers towards environmental condition of the lake and fisheries resources was analyzed by quantifying Weighted Average Index (WAI). The measure of attitudes was based on the application of Likert scale technique in the questionnaires. An index between 0 and 1 was developed from five or four point scale of satisfaction and performance. The highest weight 1 (5/5 = 1) is given to the 'strongly agree', the weight of 0.8 (4/5 = 0.8) is given for 'agree' and so on. The weighted average index was calculated with the following formula:

$$WAI = \frac{f\,5 \text{ x } 1 + f\,4 \text{ x } 0.8 + f\,3 \text{ x } 0.6 + f\,2 \text{ x } 0.4 + f\,1 \text{ x } 0.2}{F_{total}}$$

WAI	= weighted Average Index
f_1 to f_5	= frequencies of the factor (1 to 5)
F_{total}	= total frequency

The level of magnitude for each perception was determined by grouping the index value into three range namely high, medium and low level.

3.5.2.2 Developing typology of fishing households

One of the most commonly used extraction technique, PCA is applied to determine the smallest number of factors that can represent the best relationships among common quantitative variables of a sample (Pallant, 2005), and also for reducing complexity of the data, and best explaining the diversity patterns of a studied sample. Thirteen variables were selected to identify those that most contribute to the heterogeneity of the 200 sampled fishing households in Singkarak Lake. Since households commonly combine diverse livelihoods, with fisheries as pivotal one, variables used in PCA and CA are not solely related to fishing activities but are also related to farming and off-farm activities and sources of income.

Steps involved in the PCA analysis are described based on Pallant (2005) as follows:

1. Checking the suitability of data used for analysis

   Two main issues consider to pre-evaluate whether the data is suitable for PCA analysis or not namely number of sample and the strength of relationship among variables. Tabachnick and Fidell (2001) suggested the minimum number of sample size is 300. However, the smaller sample size (for example, 150 cases) should also be sufficient if the loading values above 0.80. Other authors suggested to consider the ratio of subjects to items instead of number of sample. Such as 10 : 1 ratio which means 10 cases to for each item to be factored (Nunnally 1978 cited in Pallant 2005). This study use 200 cases which is beyond the suggested number of samples. The second issue to consider is the relationship among variables. For this purpose, correlation matrix of the variables were tested and found that the coefficient is mostly greater than 0.3 as suggested by Tabachnick and Fidell (2001). Factorability of data can be assessed by other measures; Bartlett's test of sphericity and Kaiser-Meyer-Olkin (KMO). Those values are presented from SPSS results. Value of KMO should be 0.6 or greater and Bartlett's test of sphericity should be significant at 0.05 or smaller. If the results fulfill those requirements, the data is suitable for factor analysis.

2. Factor extraction

   In this stage, principal component approach was used to determine the smallest number of factors that can be extracted to represent relationship among the variables. The decision of number of factors to retain is made through experimenting various number of factors until satisfactory solution is found. Using Kaiser's criterion, the factors retain for further analysis are those with eigen value equals to or greater than 1. Parallel analysis was also conducted to determine the appropriate number of component retained for analysis. This can be done by comparing list of eigen value obtained from the table (spss analysis) and eigen values generated by other statistical program. Monte carlo for PCA parallel analysis (developed by Watkins, 2000) was used to generate eigen values of the samples by inserting the information regarding number of samples, number of variables and number of replication. If the value from spss analysis is larger than eigen value from parallel analysis, the factor is retained, if it is less than value from parallel analysis, the factor is rejected.

3. Factor rotation and interpretation

   After getting the number of factors retained for analysis, interpretation of each factor was conducted by rotation thus it is easier to interpret. Varimax rotation was performed on the thirteen selected variables. Then interpretation of the results was presented based on the factor rotation supported with existing theories and previous researches.

In the next step, fishing households were clustered using the new factors. Cluster analysis is a statistical methods in grouping samples which have homogenous classes to produce an operational classification. In this study, the sets of variables retained from PCA are the basis of fishermen's household typology by applying hierarchical cluster, using ward's method and Euclidean distance as used in (Joffre & Bosma, 2009) and (Tzanatos et al., 2005). Since we did not know how much clusters should we make for the given samples, two steps of cluster analysis were applied:

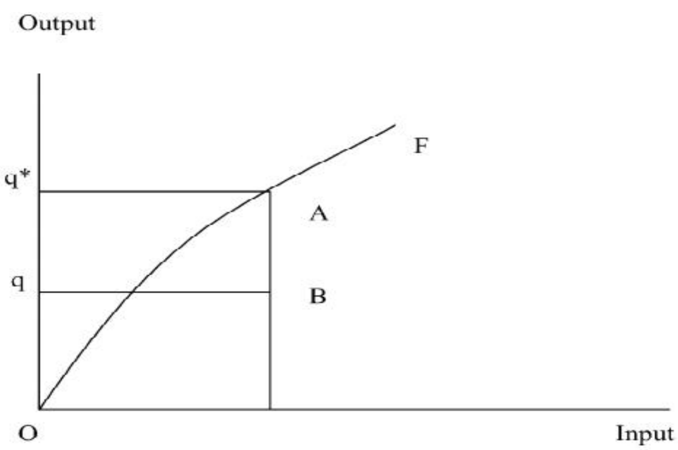
1. Hierarchical cluster analysis by wards methods and squared Euclidean distance for similarity measures. Possible number of cluster from the given samples would appear from this analysis as described from dendogram.
2. K-means cluster analysis was used to acquire the cluster center by inserting the number of clusters derived from hierarchical analysis. Thus, k-means cluster placed the cases into different group.

Cluster analysis is an important tool particularly for the population which cannot be differentiated by the “naked eye” (Atlas & Overall, 1994), which is the case here, since all households are related to fishing, but to different extents. The analysis shows the optimum number of clusters of the data set. The distance between clusters is measured based on variance analysis. Then, from the original value of indicators mean, one-way ANOVA and a Games and Howell post-hoc tests are employed to identify which variable is significantly different between the groups.

3.5.2.3 Quantifying fishing efficiency

Efficiency analysis of fishing households was performed by using a linear programming technique, Data Envelopment Analysis (DEA). DEA is principally based on production frontier that describes relationships between number of outputs and inputs; the maximum outputs produced from a given combination of inputs at certain period of time called output orientation (Pascoe & Mardle, 2003) or maximum combination of inputs to produce a given level of output (input orientation).

Technical efficiency measures the ability of a production unit to produce maximum output with given set of inputs. The use of production frontier approach in measuring efficiency is widely used as an alternative but the application of this methods in fisheries is rather limited (Fousekis & Klonaris, 2003). Figure 3.4 describes simple production process with one input and output variable.



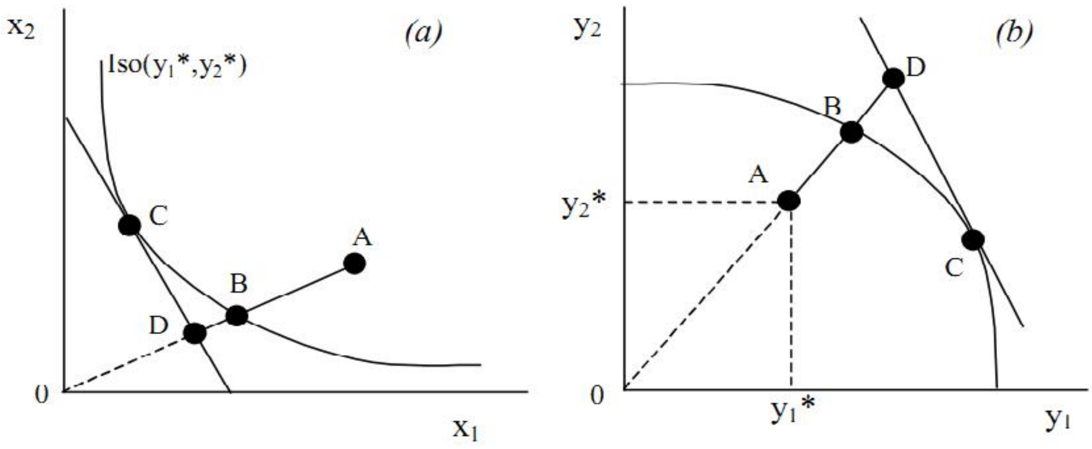
Source: Fousekis and Klonaris (2003)

Figure 3.4: Technical Efficiency and Inefficiency

Measurement of efficiency is based on the deviations of observed output from efficient production frontier. The production frontier is represented with OF. A and B are the production unit. A is technically efficient because it operates at the production frontier, technical efficiency score for this production unit is 1. Meanwhile, B is technically inefficient because the operation deviates from production frontier. Technical inefficiency score for B is q/q*.

Production frontier could be either stochastic or deterministic. In stochastic production frontier, maximum potential output from a given set of input is a random variable while the deterministic frontier, maximum output for a given input level is a scalar. There are two approaches commonly used in measuring efficiency, namely parametric approach involving the stochastic production frontier (SPF) and non-parametric approach involving data envelopment analysis (DEA). SPF was developed by Aigner et al. (1977) and Meuseen and van den Broek (1977). Stochastic measurement include random error estimation thus only deviations caused by controllable decision attributed to inefficiency measures (Esmaeili, 2006). Contrary, DEA is a deterministic approach where any deviation related to inefficiency. Several studies have compared the use of parametric and non-parametric approach in measuring efficiency (García del Hoyo et al., 2004; Ghee-thean et al., 2012; Herrero, 2005). The weakness of stochastic production frontier approach is the biased estimation technical inefficiency moreover, selection of inefficiency effects may be randomly selected (Coelli, 1995). The advantage of DEA is the ability to measures efficiency of multiple inputs and outputs. DEA results would give sources and amount of inefficiency for each inputs and outputs variable, also identify the efficiency set used to effect and identify the amount of inefficiency (Cooper et al., 2007). However, the disadvantage of DEA is the inability to isolate technical efficiency from random noise because of its non-stochastic feature (Lovell, 1993). Apart from advantage and disadvantage of those two mainly used approach in measuring technical efficiency particularly for fisheries sector, the use of DEA has been recommended by FAO (1998) as measurement tools for efficiency analysis. Thus, study on technical efficiency and fleet capacity in fisheries has evolved (Dupont et al., 2002; Esmaeili, 2006; Idda et al., 2009; Kirkley et al., 1998; Madau et al., 2009). DEA may be used to calculate fishing capacity in single or multiple species and possibly for measuring by-catch.

Efficiency can be measured from input orientation or output orientation. From an input-oriented efficiency shows an optimum combination of inputs to produce given level of output. While output orientation measures define optimum combination of output which can be produced with the current set of inputs. Figure 3.5 shows efficiency measures from input and output orientation. Figure 3.5(a), a production unit could produce output level at (y_1*, y_2*) from input combination at point A. in order to achieve the same level of output, inputs level could have been reduced back to point B which lies on the iso-quant line showing the minimum level of inputs to produce (y_1*, y_2*). Thus, technical efficiency from input-oriented (TE-I (y,x)) measures is defined by 0B/0A.



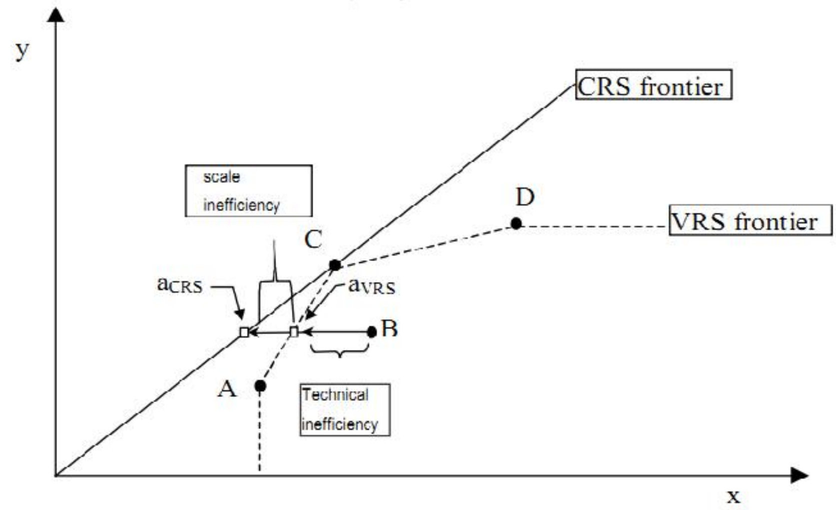
Source: Pascoe and Mardle (2003)

Figure 3.5: Input (a) and Output (b) Oriented Measures of Efficiency

From an output orientation of efficiency measures in figure 3.5(b), the output can be increased from point A to B if the production unit used the inputs more efficiently. The technical efficiency from output-oriented (TE-O (y,x)) measures is defined by 0A/0B. Hence, B is technically efficient because it lies on the production frontier. However, higher revenue could be achieved by producing at point C where marginal rate is equal to price ratio p_2/p_1. More y_1 should be produced and less y_2 to get maximum revenue. The same level of revenue could be achieved with the same input and output combination by expanding to point D. Revenue efficiency (RE(y,x,p)) is given by 0A/0D.

In DEA, technical efficiency measures enable us to apply different approaches such as constant returns to scale (CRS), variable returns to scale (VRS). Under CRS approach, it is assumed that the scale of production would not affect the efficiency level. While under the VRS approach, the scale of production could be affect by the technology factor. Such the case of fisheries, technical change is considered non-neutral which means the effect could be differentiate by boat size, fishing gears and other possible factors in fishing (Pascoe & Herrero, 2004), thus variable returns to scale is more applicable for this case.

Figure 3.6 explains the difference between two approaches of efficiency measure (CRS and VRS). The figure represents some particular firms producing single output (y) by using single input (x). The production frontier for CRS is given by the line from origin through C. the production frontier based on VRS is given by the line A, C and D. Point a_{VRS} shows the amount of input x needed to produce the same amount of output y which serves as reference point for firm B. Point a_{CRS} represent the input used if the firm was both technical efficient and operated at optimum scale. Firm C is the only firm having highest output per input under CRS frontier, thus firm B is suggested to increase the scale to reduce inefficiency caused by too small scale.



Source: Pascoe and Mardle (2003)

Figure 3.6: Production Frontier for CRS and VRS Approach Using Single Output and Input

Brief discussion of DEA model is presented with technical detail. In DEA, the term decision making units (DMUs) referring to set of entities which process multiple inputs into (multiple) outputs. Technical efficiency measures involved two approaches namely input or output orientation. Following Fare et al. (1994), considering J producers using N inputs to produce M outputs, inputs and outputs are assumed as follows:

(i) $U_{jm} \geq 0, X_{jn} \geq 0$

(ii) $\sum_{j=1}^{J} U_{jm} \geq 0, m = 1,2,\ldots,M$

(iii) $\sum_{n=1}^{N} X_{jn}, > 0, j = 1,2,\ldots,J$

(iv) $\sum_{j=1}^{J} X_{jn}, > 0, n = 1,2,\ldots,N$

(v) $\sum_{m=1}^{M} U_{jm}, > 0, j = 1,2,\ldots,J$

Where U_{jm} equal to the quantity of the m-th output produced by the j-th producer and X_{jn} is the level of n-th input used by the j-th producer. Condition (i) assumed that each producer use non-negative amounts of each input to produce non-negative amounts of each output. Conditions (ii) and (iii) indicate total production of positive amounts of every output and total employment of positive amounts of every input. While conditions (iii) and (v) require that each producer employ positive amount of at least one input to produce a positive amount of at least one output. In addition to input and output orientation, we can also determine the model of production unit relative to various returns to scale. Considering constant return to scale (C) and strong disposability of inputs and outputs (S), the condition is described as:

$$L(u \mid C,S) = \{X : U_m \leq \sum_{j=1}^{J} Z_j U_{jm}, m = 1,\ldots, M \tag{1}$$

$$\sum_{j=1}^{J} Z_j X_{jn} \leq X_n, n = 1, \ldots, N, z \in R_+^J\}$$

For non increasing returns to scale (NIRS), additional constraints is used

$$L(u \mid N,S) = \{X : U_m \leq \sum_{j=1}^{J} Z_j U_{jm}, m = 1,\ldots, M \tag{2}$$

$$\sum_{j=1}^{J} Z_j X_{jn} \leq X_n, n = 1, \ldots, N, z \in R_+^J, \sum_{j=1}^{J} Z_j X_{jn} \leq 1.0\}, u \in R_+^M$$

For variable return to scale (VRS) requires changing the constraints from ≤ 1.0 to = 1.0. For input set representation of the technology $L(u|C,N,V),W)$ subject to weak disposability inputs (W), need changes of the constraint in the equation (1) from inequality to an equality constraint:

$$\sum_{j=1}^{J} Z_j X_{jn} = X_n, n = 1, \ldots, N \tag{3}$$

From an output orientation, under constant returns to scale (CRS) and strong disposability, the formulation as follows:

$$P(x \mid C,S) = \{U : U_m \leq \sum_{j=1}^{J} Z_j U_{jm}, m = 1,\ldots, M \tag{4}$$

$$\sum_{j=1}^{J} Z_j X_{jn} \leq X_n, n = 1, \ldots, N, z \in R_+^J\}$$

Non-increasing returns to scale (NIRS) and variable returns to scale (VRS) model use the same constraints on the summation of intensity variables as it is formulated for input orientation.

$$U_m = \sum_{j=1}^{J} Z_j U_{jm}, m = 1, \ldots, M \tag{5}$$

Based on equation (1) on piece-wise technology $L(u \mid C,S)$, technical efficiency measures of decision making unit from input orientation presented from the following linear programming:

$$TE_{ij}(U_j, X_j \mid C,S) = \min_{\lambda,z} \lambda \tag{6}$$

Subject to: $U_{jm} \leq \sum_{j=1}^{J} Z_j U_{jm}, m = 1, \ldots, M,$

$$\sum_{j=1}^{J} Z_j X_{jn} \leq \lambda X_{jn}, \; n = 1, \ldots, N,$$

$$Z_j \geq 0, j = 1, 2, \ldots, J$$

Where λ is the measure of TE; z is the intensity vector; J represents the number of DMUs; M and N are the number of outputs and inputs respectively. For the NIRS and VRS model of TE, the linear programming is presented by imposing constraints in the equation (2) for VRS; weak disposability requires the constraints from equation (3).

The linear program for an output oriented measure of TE is equally constructed:

$$TE_{0j}(U_j, X_j\ C, S) = \max_{\lambda,z} \theta$$

Subject to: $\theta U_{jm} \leq \sum_{j=1}^{J} Z_j U_{jm},\ m = 1, \dots, M$

$$\sum_{j=1}^{j} Z_j X_{jn} \leq X_{jn}, n = 1, \dots, N$$

$$Z_j \geq 0, j = 1, 2, \dots, J$$

Where TE_0 is TE under output orientation showing the maximum feasible or proportional increasing of the outputs. θ equals to the ratio of the maximum potential output to observed level of output. The value of θ is restricted to ≥ 1, some package DEA software estimate the level of TE as $TE = \frac{1}{\theta}$ with $\theta - 1$ is the proportionate increase of outputs level. If the value of $\theta = 1$, the production of DMU is technically efficient, if $\theta \geq 1$, the production is inefficient, hence the output level can be increased by $\theta - 1$.

In fisheries, technical efficiency from an output-oriented perspective represent the measure of the vessel ability to produce the best outputs level from a given set of inputs subject to the production technology, resource levels, weather conditions, and other technological constraints (Kirkley et al., 1998). While from the input orientation TE measures shows the largest inputs reduction possibility and still produce the same level of outputs.

This study discusses technical efficiency (TE) of fishing households computed by variable returns to scale (VRS) model and input oriented. In this research, DMUs are surveyed households with identified and quantified production (fisheries) inputs and outputs. The optimal “production frontier” is drawn by the most efficient DMUs, i.e. the ones that show higher outputs with lower inputs. The model results in relative technical efficiencies as per DMU.

Technical efficiency in fisheries measures the relationship between the fishing inputs and its outputs within fishing process, from an output-oriented perspective maximizing the outputs with the given level of inputs would achieved the full efficiency (Tingley et al., 2005). Following Madau et al (2009); Maravelias and Tsitsika (2008); Tingle et al (2005), the DEA linear programming model applied is based on estimation of Fare et al (1989, 1994). Linear programming for an input-oriented measure of TE for a given vessel is as follows:

$$TE_{ij}\left(U_j, X_j \mid C, S\right) = \min_{\lambda,z} \lambda$$

Subject to: $U_{jm} \leq \sum_{j=1}^{J} Z_j U_{jm}, m = 1, \dots, M,$

$$\sum_{j=1}^{J} Z_j X_{jn} \leq \lambda X_{jn},\ n = 1, \dots, N,$$

$$Z_j \geq 0, j = 1, 2, \dots, J$$

$TE_{ij}(U_j, X_j \mid C, S)$ is technical efficiency of j-th DMU under constant return to scale (CRS) where there is no change of output level by the potential reduction of the given inputs. λ is the measure of technical efficiency which is equals to minimum feasible input usage to the current input usage with value $0 \leq \lambda \leq 1$ (Fare et al., 2001). $TE = 1$, depicts that the vessel is technically efficient, $TE < 1$, implies that the production is technically inefficient. Z_j is the intensity variable which enable benchmark frontier for vessel j and λ_{jn} represent input utilization rate by vessel j for variable input n. M and N represent number of outputs and inputs, respectively. To solve linear problem under NIRS and VRS, modification is needed by imposing constraint in the equation below:

$$L(U \mid N, S) = \{X: U_{jm} \leq \sum_{j=1}^{J} Z_j U_{jm}, m = 1, \dots, M$$

$$\sum_{j=1}^{J} Z_j X_{jn} \leq X_n, n = 1, \dots, N, z \in R_{+,}^{J} \sum_{j=1}^{J} Z_j \leq 1.0\}, U \in R_{+}^{M}$$

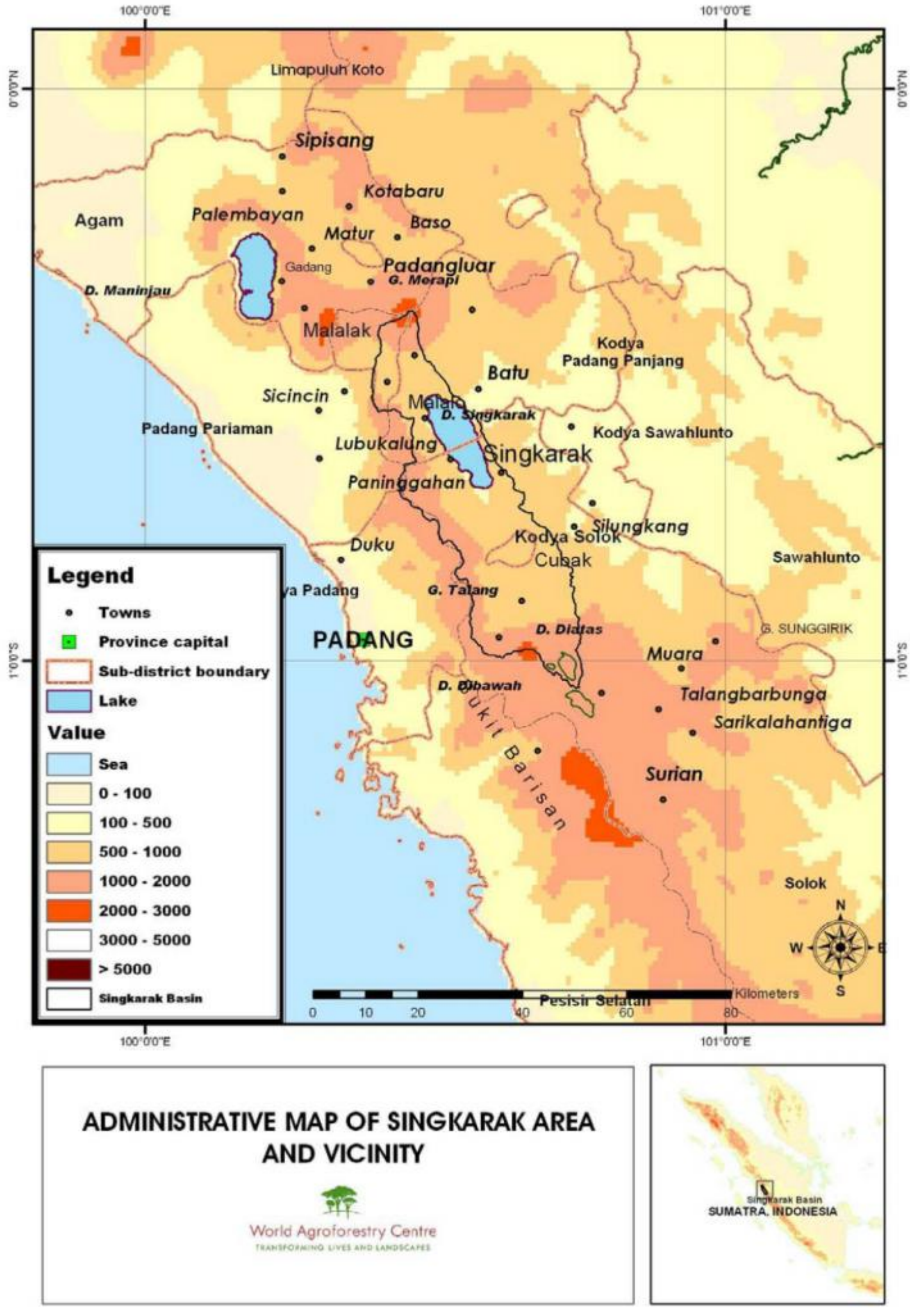
For VRS, $L(U \mid V, S)$, imposing the constraint as the summation of the intensity variables from ≤ 0 into $= 1$.

Scale efficiency (SE) is defined as the ratio of comparison between two technical efficiency of CRS and VRS (Fare et al., 2001). It measures whether a production unit is operating at optimal scale. $SE = \frac{TE_{CRS}}{TE_{VRS}}$, production is scale efficient if $TE_{CRS} = TE_{VRS}$ or $SE = 1$. Scale efficiency can be measured by input or output orientation. In this study, SE is based on the input orientation. SE measurement in fisheries is relevant to seek the answer of what would be optimal scale of operation. However, scale efficiency is simply shows whether a production unit is scale efficient or not. Scale efficiency measures could not shows whether the production unit is characterize by increasing or decreasing return to scale (Fare et al., 2001). In order to solve this issue, non-increasing return to scale (NIRS) model is applied. We can determine whether production unit operate as too large or too small scale (increasing or decreasing return to scale) through the comparison of TE_{CRS} and TE_{NIRS}. General rules in defining relationship between TE_{CRS} and TE_{NIRS} for input oriented model are: (1) if SE < 1, indicates that the production unit is scale inefficient; (2) if SE < 1, and $TE_{NIRS} = TE_{CRS}$, production unit inefficient because of increasing returns to scale; (3) if SE < 1, and $TE_{NIRS} > TE_{CRS}$, production unit operating inefficiently at large output level in the area of decreasing returns to scale. From an output oriented model, (1) if SE > 1, production unit is scale inefficient; (2) if SE > 1 and $TE_{NIRS} = TE_{CRS}$, inefficiency is due to increasing returns to scale; (3) if SE > 1 and $TE_{NIRS} > TE_{CRS}$, production unit is inefficient because of decreasing returns to scale. Returns to scale in this study is determined from an input orientation.

Chapter 4

Overview of Study Area

This chapter provides the overview of Singkarak Lake and its biophysical characteristics including the basin area, socio-economy, land use, cultural and political setting. In addition this chapter also provides brief description of adjacent areas to the lake.



Source: Farida et al (2005)

Figure 4.1: Map of Singkarak Lake showing sub catchment area in Singkarak Basin

4.1 Geographical locations and biophysical of Singkarak Lake

Singkarak is the largest lake in West Sumatra and one of the important water bodies that provide livelihood to people. The lake is part of Singkarak – Ombilin Basin. The basin is located within the geographical coordinates of longitude W100^{o}26’15”, E100^{o}35’55” and latitudes of N0^{o}31’46” and S0^{o}42’20”. This basin consists of main sub-basins namely Singkarak sub-basin in the upstream area (western part) and Ombilin sub-basin in the downstream (eastern part). The Singkarak sub basin covers an area of 1135 km^2 comprises of hilly and mountainous area with igneous volcanic rock in some parts of its area. Ombilin river sub basin categorized as tertiary volcano covers an area approximately 1114 km^2. Conversely to Singkarak sub basin, the area of Ombilin river sub basin is relatively flat (Center for Soil and Agro-climate research Agency, 1990).The elevation of its basin ranges from 240 – 2760 m above sea level and the lake was formed by eruption of volcano during Quarternary period.

Singkarak Lake covers two districts; namely; Tanah Datar (Batipuh and Rambatan sub-district) and Solok (X koto Singkarak and Junjung Sirih sub-district). The catchment area of the lake is located within four regions; Solok and Tanah Datar district, Padang Panjang and Solok city. There are 13 Nagari[2] which are directly attached to the lake; some of the Nagari are the central to fishing activities. The size of the lake is about 136.65 km^2, with 160 m in deep, 21 km long and 16 km wide (Arifin, 2005). This data is slightly different compared to data from Sunda expedition which was conducted in 1939. Based on this expedition, characteristics of Singkarak Lake is described follows:

Maximum total area	: 122.20 km^2
Area around	: 61.00 km
Maximum long	: 20.00 km
Maximum width	: 16.50 km
Maximum depth	: 296.00 m
Average depth	:136.00 m

4.2 Hydrology, drainage and climate

Hydrological condition of Singkarak Lake is influenced by surface water and groundwater. Surface water is mainly from rivers and streams flowing into the lake which depend on rainfall. The dynamic water level of Singkarak Lake is greatly influenced by the river flow hence affect land management particularly in agricultural area surrounding the lake (Subagyono et al., 2008). There are for about 18 rivers (big and small), with the biggest length 51.5 km flowing into the lake. Most of the rivers have fewer debits during dry season. It is estimated that average inflow of Singkarak Lake approximately 37.99 m^3/sec, ranging from 28.55 m^3/sec – 64.29 m^3/sec[3]. Mean monthly rainy days ranging from 5 to 24 days with daily evaporation 3.9 – 5.3 mm. Average temperature in this area is 22.5 – 26.2^{o}C and the average rainfall in Singkarak Lake Sub Basin is 2,026 mm/year. There are five main rivers (*batang*) drained into Singkarak Lake including Batang Malalo from the

[2] *Nagari* is the name of the traditional village, pre-colonial political units of Minangkabau political organization (von Benda-Beckman, F. and von Benda-Beckmann, K. 2001)
[3] Laporan akhir studi pengelolaan Danau Singkarak oleh PT. Modulatama Intikreasi

west (Tanah Datar district), Batang Ondoh, Batang Paninggahan, Batang Saniang Baka and Batang Sumani, those four rivers are from the south (Solok District). Sumani River (annual average of rainfall is 2,201 mm/year) in the southern part, Paninggahan and MuaroPingai River from the west. Sumpur River, with average rainfall 2,484 mm/year is another source of water from the north part. The outflow the Lake drains into Ombilin River and water use for operation of Hydro Electric Power Plant (HEPP), generating 175 MW which was operated since 1998. Table 4.1 shows the probability and average debit inflow of Singkarak Lake based on hydrological year.

Average outflow from the lake is 42.02 m^3/sec with the interval minimum and maximum outflow 31.04 – 47.78 m^3/sec. Previously there was only one natural outlet from the lake namely Batang Ombilin in the east part of the Lake. This river serves water needs for people in the downstream area of four districts; Solok, Padang Pariaman, Tanah Datar and Sawahlunto Sijunjung, in particular for irrigating rice-fields. Another outlet (artificial) was built to the west for generating hydroelectric power plant (HEPP). Despite of its ability to provide electricity (175 MW) serving west Sumatra and Riau Province, the HEPP has threatened water users in the downstream area (Batang Ombilin) because of decreasing outflow water debits.

Table 4.1: Probability and Average Debit of Inflow

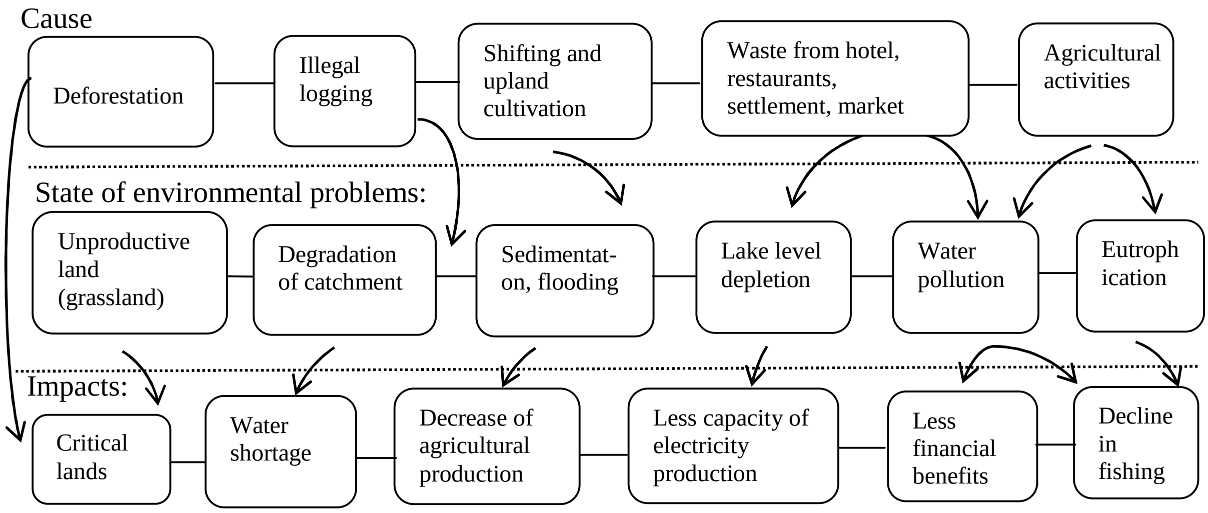
No	Hydrological year	Probability of occurrence	Average yearly debit (m^3/sec)
1	The wettest	0 – 2%	> 58.05
2	Wet	20 – 40%	49.92 – 58.05
3	Normal	40 – 60%	42.21 – 49.92
4	Dry	60 – 80%	35.13 – 42.21
5	The driest	80 – 100%	< 35.13

Source: PT. (Persero) PLN Pikitring West Sumatra – Riau

4.3 Environmental problems: the roots causes, changes and impacts

Local people perceive water quality and fluctuation of lake level as the emerging environmental issues. Based on reviews of documents and secondary data from relevant institutions, Singkarak Lake environment is presented in figure 4.2 covering relationship among causes, states and impact of environmental degradation.

The arrows in figure 4.2 depict direct relationship between cause, changes and impacts of environmental issues linearly. In fact, there exists more complex relationship among those three groups (cause – state – impact) and interaction of each component within each group. However, the focus of this figure is stating environmental issues that affect local people livelihoods. The emerging environmental issues include unproductive land in the form of grassland, degradation of catchment area, sedimentation, lake level fluctuation, water pollution and eutrophication. This condition has impacted upon declining fish catch thus less financial benefits of the fishers. On the other hands, declining catch and financial benefits might also trigger the worse fish decline because of inappropriate fishing practices (such as putting more fishing efforts, using smaller net mesh size or destructive fishing practices).



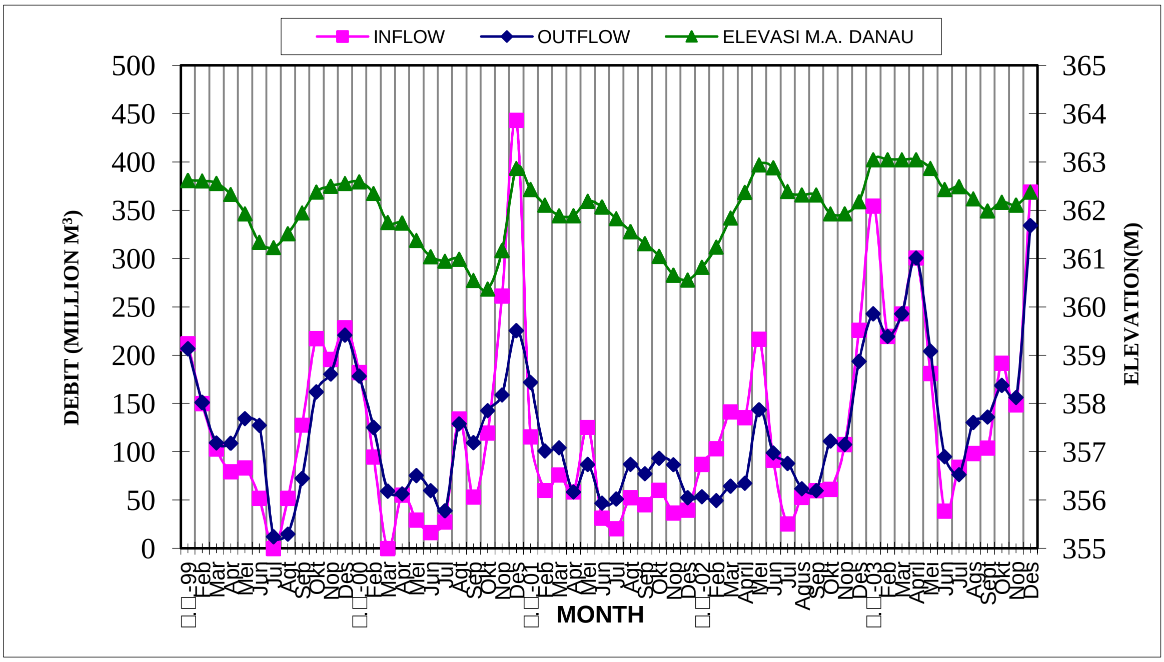
Source: adapted from Farida et al (2005), Ministry of Environment (2006)

Figure 4.2: Cause and Effect Relationships of Environmental Problems in Singkarak Lake

During 1999 – 2002, (one year after the operation of HEPP), water level is found to be decreased in significant number from 363 m dpl (max) and 362 m dpl (min) in 1999 into 362.94 m dpl (max) and 360.82 m dpl (min) in 2002. Based on data from National Electricity Enterprise (PLN), the maximum lake level was 363.33 m that occurred on 27 December 2002, while the minimum lake level occurred in 9th to 10th December 2001 with the level of 360.48 m. Depletion and fluctuation of lake water has caused changes in productivity of water use, such as decrease of water supply for hydroelectric power and agriculture. State electricity company (PLN) would stop the operation if water level is below 359.5 meter. Normal operation area is at water level above 361 meter.

Elevation or level of the lake is monitored regularly since the operation of Hydro electric power plant (HEPP). Figure 4.3 shows the fluctuation of lake level from 1999 – 2003. The fluctuation of annual rainfall in this area accompanied by HEPP operation has aggravated depletion of lake level in Singkarak Lake. Local people noticed that fluctuation of lake level has been experienced since the operation of HEPP. Water generated electricity in Singkarak Lake is reverted to Batang Anai River instead of the lake. The use of water to generate electricity will not affect the quantity of the lake if the water use to generate turbine is reverted to the lake.

Water quality problem is mainly caused by the discharge of market and households waste and forest degradation in the upstream. The intensive use of fertilizers to increase crop production and yield has badly affected the quality of water. Those contaminants cause depletion of dissolved oxygen that threatens fish and other aquatic organisms. The presence of contaminants and wastes in water tend to cause high turbidity that can inhibit the growth of bilih fish (Juita, 1995). Data on water quality monitoring is not available because water quality measurement was not conducted regularly. Water quality is only measured at particular occasion by different agencies. Compiling from some source, data on water quality of the lake is presented in table 4.2.



Source: National electricity enterprise (PLN)

Figure 4.3: Elevation of Singkarak Lake Level, Inflow and Outflow (1999 – 2003)

Table 4.2 describes changes of water quality at particular year. Although it does not show the trend of the changes annually, yet it still can describe status of water quality in Singkarak Lake. Some parameters shows the increase of pollutant concentration and above water quality particularly BOD and total phosphate. Meanwhile, COD and DO value was fluctuate; measurement in 2008 shows the increase of COD and DO above the standard value. This is due to the source of pollutants which is mainly from domestic, industrial and agricultural wastes. Those types of pollutant contain organic substances which stimulates the growth of algae and other microorganisms.

In addition, degradation at the catchment area has accelerated erosion and sedimentation in the lake which in turn damaged littoral zone as the reproduction and breeding area of the fish. Lembang River and Sumani River are considered as the most degraded catchment area of Singkarak Lake (Planning, public works, and environmental agency of Solok District). Since there has not yet been any measurement of this catchment in terms of its sediment, the estimation is based on the physical appearance of the river water that looks turbid and the water has brown color. Run-off from degraded catchment area in Singkarak Basin flowing into the rivers or lake generate sedimentation problem which in turn exacerbate lake condition. Sedimentation can cause severe impact on the quality of water because higher concentration of pollutants is deposited in sediments. Sedimentation is also related to flooding. Heavy rain cause meandering and bring soils from catchment area. The erosion from degraded catchment area would reveal worse impact to the environment.

Table 4.2: Water Quality Measurement in Singkarak Lake

Parameter	Unit	Standard	Year					
			1984	1993	1997	2006	2007	2008
			Physical					
Temperature	^oC		27	26	27.6	29	30	28
Total dissolved solid (TDS)	mg/L	1000	-	-	-	91.8	93.6	5.4
Total suspended solid (TSS)	mg/L	50	-	-	-	2	17	2
			Chemical					
pH	Unit	6 – 9	8.4	7.5	8.4	6.5	6.5	5.8
BOD	mg/L	3	-	-	-	4.58	6.8	12.56
COD	mg/L	25	-	-	-	18.7	39	31.68
DO	mg/L	4	6.6	-	8.3	6.34	4.3	6.3
Total phosphate	mg/L	0.2	0.19	0.02	0.36	0.43	0.46	0.59
Ammonia	mg/L	1.5	0.19	-	0.54	-	-	-
$N\text{-}NO_3$	mg/L	10	0.14	-	0.172	1.03	< 0.1	< 0.1
$N\text{-}NO_2$	mg/L	0.06	X	-	0.03	X	0.001	0.002
Fe	mg/L	0.3	X	-	0.05	X	0.03	0.03
H_2S	mg/L	0.002	-	-	-	X	0.002	0.002
Detergent as MBAS	mg/L	200	-	-	-	21	< 20	< 50
DDT	µg/L	2	-	-	-	X	X	X
Chloride	mg/L	1 – 2	-	-	-	X	X	X
			Microbiology					
Fecal coliform	amount/ 100ml	100	-	-	-	X	25	25

Source: 1984 – PSLH, Andalas University; 1993 – Syandri, 1996; 1997 – Simon et. al., 2000; 2006, 2007 and 2008 – Syandri, 2008.

X : undetected
- : did not analyze

Sumani River as one of the main inlets flowing into Singkarak Lake, flowing from Solok urban area which brings domestic and agricultural waste. This area contains quiet high Nitrogen concentration which is 0.206 – 1.375 mg/l and contains 0.004 – 0.075 mg/l phosphorous (Sulawesty et al., 2001). The ratio of total nitrogen and total phosphorous is in the range of 15.5 – 74.4. The vast algal growth result in decrease of oxygen concentration in water, threaten the fish growth. Furthermore, physical characteristic of polluted water that has high turbidity could not support the growth of the fish particularly bilih fish. There is relationship between turbidity and growth of bilih fish, the higher water turbidity, the longer time for incubation of the embryo and the slower process of hatchery (Juita, 1995).

Lakeside dwellers that rely on the goods and services provided by the lake for their livelihoods are affected by changes of ecosystem of the lake. Fishermen are one of the groups suffered from water quality depletion and fluctuation. Informants note that deterioration of water quality and fluctuation of water levels in the lake has affected the fish population, which in turn has caused a diminishing fish catch. They realize, however, that the decline in fish catch is not only caused by water quality deterioration. These conditions have led to a decrease in household income that it is difficult for fishermen to fulfill their basic needs. Those affected fishermen have different ways of dealing with this stress. Some of them diversify their livelihoods as the merchant or driver. Those who usually do both fishing and farming, devote more time for farming activities rather than fishing. In some families, the wife involves in income generating activities as labor or helping their husband working in the farm.

Farmers who depend on the outflow of Singkarak Lake for irrigation are also affected by the fluctuation of lake level. They use traditional waterwheel made of bamboo to generate water for irrigation to their rice field. This is the cheapest and most feasible methods for irrigation because the rice field is located at higher place than the river. The ability of waterwheel to irrigate rice field is totally depend on the availability of water. The farmers are experiencing difficulties to get enough water supplies for their rice field since the decrease of outflow into Ombilin River. This condition results in the decrease of crop yield. In addition, the decrease of Singkarak Lake outflow has also diminished another source of income for the farmer namely fishery sector. Before the decline of water outflow, most of the farmers have inland fish pond at the edge of the river. The decrease of water flow makes the pond dry and all the fishes were died. Some of the farmers change their crops plantation from rice to other plantation such as cassava that consumes less water. However, the yield is much lesser than rice production. Perception of local people on fisheries resource condition and causes of degradation is presented in the next sub-section of this chapter. The major contaminants are organic substances from domestic wastes, pesticides, and industrial wastes.

4.4 People response to environmental problems

Resource degradation and poverty are interlinked in a system called social ecological system. It implies the dependence of human to resources hence degraded resources would highly impact upon their livelihood. How do people react on the risks and negative changes of environment, economic, social or political condition is defined as vulnerability (Rakodi, 1999). In the sustainable livelihood framework, vulnerability comprised of three main factors that influence people's livelihood assets (DFID, 1999). Those factors are trends, shocks and seasonality. Shocks can occur from nature, human, economic factors such as floods, storm, drought, conflict or even the depletion of crops or livestock's health. Scoones et al., (2007) made distinction between shocks and stresses assuming temporality of changes both are changes seen as short-term shocks or long-term stresses. Shocks are defined as 'transient disruption in an otherwise continuous trajectory' while stresses are 'enduring and pervasive cellular long run shifts'. In this context, the distinction made for environmental issues in Singkarak Lake which is grouped into shocks and stresses (Domptail et al., 2013).

Table 4.3 shows overview of considered shock and stresses as well as their main impact confronted by lake dwellers in particular fishing community in Singkarak Lake. Shock refers to environmental nature and affect the ability of the fishers to generate income from their resources in short-time. Bangai is a type of shock faced by fishers. It causes massive death of fish. The last bangai was happened in Stresses considered here are ecological (water pollution, depletion and fluctuation of lake level) and socio-economic factor (increasing number of fishermen). based on the framework by Scoones et al. (2007) and Leach et al. (2010), the actions as control to shocks and stresses address the stability and durability of the system. While response to shocks and stresses address two types of system properties namely resilience and robustness (Figure 4.4).

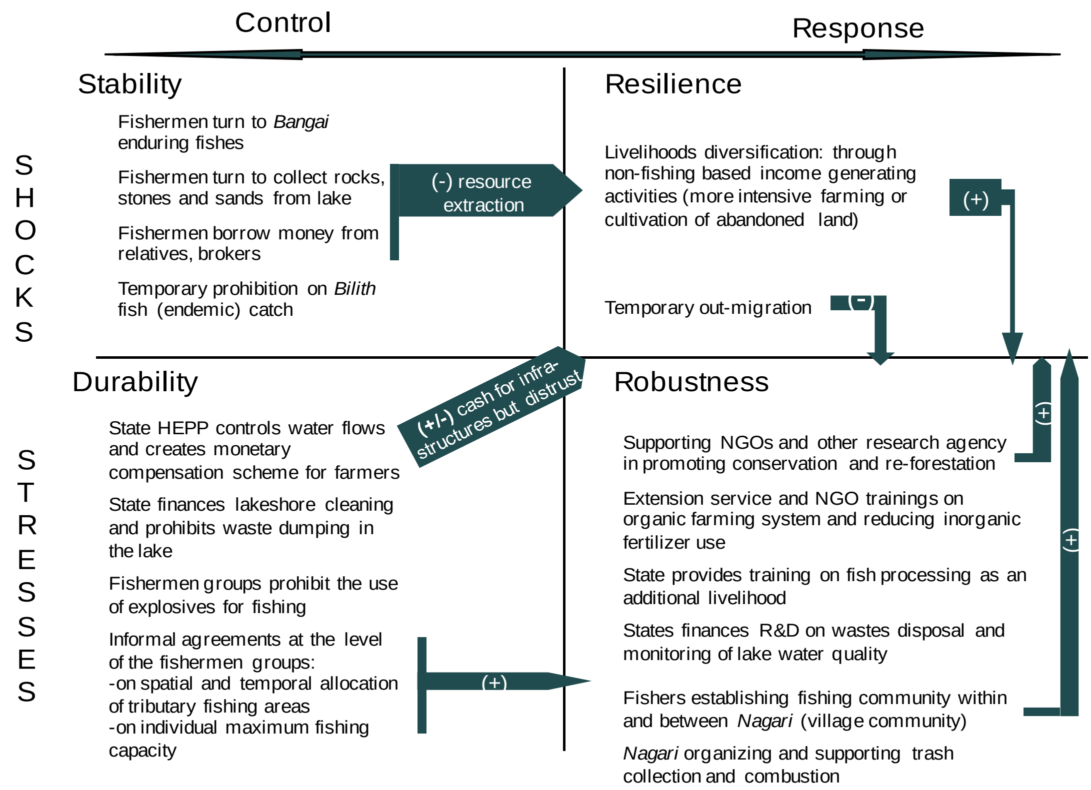
Table 4.3: Overview of the Considered Shocks and Stresses and their Impacts

Shock. "*Bangai*"	Natural calamity (up-welling of low lake waters containing sulphuric acids, nitrates and ammonia) causing massive death of fish. Usually occurs every 10 to 15 years.
Stress1. Water pollution	Through pesticides, fertilizers, domestic and small scale industrial wastes. Impacts resource users' health and fish stocks
Stress 2. Depletion and fluctuation of lake level	Associated with water usage by Hydro Electric Power Plant (HEPP), more variable rainfalls and erosion in the catchment. Affects fish reproduction and catch, and farming.
Stress 3. Increasing number of fishermen	Decreases the available resource per head of user. May lead to over fishing and resource depletion or poverty.

Source: author's research and adapted from Domptail et al (2013)

The framework of resilience and robustness is applied to socio-ecological system in Singkarak Lake through two steps: (i) selection of relevant and typical driver of change in Singkarak Lake; (ii) the response of the fishers and government to the selected driver of change in maintaining their livelihood. Source of information are the local and national news articles, local scientific journal articles, government communications, personal communication with fishers, with experts and with government members, local websites, data collected and observations. The aim of this analysis to provide general background of ecological problem in Singkarak lake and the fishers, governments response as the main actors in this social ecological system.

The fishers used both responding and controlling actions. Controlling actions are made possible by the social characteristics of the system, here the capacity of the fishers community to build organizations, thereby increasing their power and apply controlling measures on the identified driver. For instance, the growing fishers population is met by a self-restrictive informal agreement to control fishing operations. Such controlling actions may even increase the resilience of the system. Shocks are of an environmental nature and affect the ability of the fishers to generate income from their resources in the short term. The fishers opt for typical risk-reduction responses such as income diversification into farming, off-farm income, livestock or fish diversification, or a switch to resistant livestock or fish. This last option has the particularity that, while increasing the resilience of the SES, it may lead to resource depletion and to a loss in the long-term resilience and in the robustness of the SES.



Source: author's research and adapted from Domptail et al (2013)

Figure 4.4: Main actions taken for the management of SESs in the face of selected shocks and stresses, and relationships between actions in Singkarak Lake

4.5 Socio-economic importance of Singkarak Lake

Singkarak Lake has complex land use pattern that plays important role for the people's livelihoods particularly for those living in its surrounding area. Among many other services that a lake can provide, provisioning services is the most important feature that the lake provides as a source of livelihood to local people. Among those, food and freshwater are the most essential provisional services of inland fisheries. People derive products from the lake for subsistence as well as economic benefits, for example, irrigation, fishing, navigation, water supply and Hydro-Electric Power Plant (HEPP). Furthermore, Singkarak Lake also provides regulating and supporting services including watershed services, biodiversity, carbon sequestration and storage and landscape beauty (Farida et al., 2005).

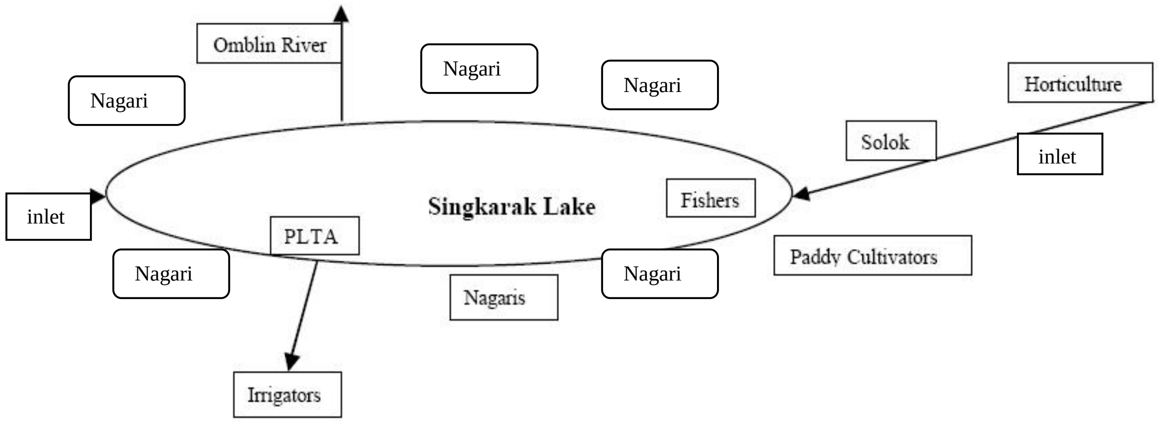
The local communities perceive that lake is important for their livelihoods from which they get benefits through fishing particularly "*bilih fish*", the use of water for bathing, washing and sanitation. In addition, they also recognize the benefits from agriculture, tourism activities, collection of woods and other materials from the lake such as wood debris carried by water from the catchment area particularly during rainy seasons. Although fishers associated only the direct benefits that they obtained from the lake and did not mention about the indirect services such as biodiversity conservation, carbon sequestration but they indicate that they avail these services as well (Table 4.4).

Table 4.4: Lake Environmental Services Identified by Local People (Fishers)

No	Group 1 (Nagari Saniang Baka)	Group 2 (Nagari Sumpur)	Group 3 (Nagari Ombilin)	Group 4 (Nagari Paninggah-an)	Group 5 (nagari Guguak Malalo)	Group 6 (Nagari Muaro Pingai)
1	Source of food (bilih fish, small shrimp, "pensi")	Source of food (bilih fish)	Source of food (bilih fish, pensi)	Source of food (bilih fish)	Source of food (bilih fish, pensi)	Source of food (bilih fish, pensi)
2	Source of water for daily needs	Tourism	Source of water for daily needs	Source of water for daily needs	Source of water for daily needs	Source of water for daily needs
3	Tourism	Source of water for daily needs	Tourism	Tourism	Tourism	Fuel wood
4	Agriculture (irrigation)	Agriculture (irrigation)	Electricity	Electricity	Electricity	Education
5	Collecting bamboo, fuel woods	Electricity	Transportation	Transporta-tion	Transportati on	-
6	Spiritual	Sport (pacu dayung)	Agriculture (irrigation)	Agriculture (irrigation)	Dumping the trash	-
7	Weather forecasting	Spiritual	Research	Research	-	-
8	Education	Research	-	-	-	-

Table 4.4 listed environmental services recognized by the fishers from different Nagari located surrounding Singkarak Lake based on the priority for each fishers group (number 1 – 8 indicates the high to low priority). All groups identified the lake is a source of bilih fish, small shrimp, *pensi* that are used as food and fresh water for daily needs as the main provision services derived from the lake. Some nagari (Muaro Pingai and Saniang Baka) also listed collecting fuel woods and bamboo as one of the benefits.

Most of the area surrounding the Singkarak Lake is rice paddy field and upland crops (38%). Settlements and intensive agricultural activities are also part of Singkarak Lake environment. Singkarak Lake is identified as potential sites for conservation due to its benefits. In addition, the lake is an area of RUPES (Rewarding Upland Poor for Environmental Services) project. The government promote conservation program surrounding the catchment area of Singkarak Lake. The beauty of area surrounding the lake and unique culture of Minangese (people's tribe in West Sumatra) has attracted tourist. The outputs of the lake are Ombilin River and an artificial output namely hydroelectric power plant supplying electricity for two provinces, West Sumatra and Riau. Singkarak Lake also support fisheries sector as the income source and important source of protein for local people and its surrounding. Due to its values and importance to people's livelihoods, there are many stakeholders group that must be considered in the management of the lake (Figure 4.5).



Source: Kerr, J (2004)

Figure 4.5: Various group of interest surrounding Singkarak Lake

4.5.1 Drinking water, bathing and washing

Most of the people living in the vicinity of Singkarak Lake use the lake water to fulfill daily water needs including drinking water, washing and bathing. However, in Tanah Datar district, there are only 42% of households that have washing and toilet facilities (SLH, Tanah Datar District, 2008). Most of restaurants, hotels, motorcycle repairing shop and houses surrounding the lake do not have sewer gate and the waste directly dump into the lake. This contributed to water quality degradation and depletion of fish production in the lake. affecting the source of income of fishermen. Even though local people realize that water quality of Singkarak Lake has decreased, they keep using lake water without any anxiety of suffering water related diseases.

4.5.2 Fisheries

Both upland agriculture and fishing contribute 77% of the total income of the people living around Singkarak Lake. Households survey data shows that average bilih catch in 2010 is 12.6 tons. The local people did not mention specifically when the fishing activities started in this lake but they confirm that they learnt fishing from their parents and is inherited from their ancestor. Fishing activities are carried out in daily basis by some groups of fishermen at main inlet river estuary namely Paninggahan, Sumpur and Lembang estuary. They usually use casting net, dragnet for fishing. However, some fishermen still practice unsustainable fishing who use electric current or explosives. Some of the fish species found in this lake are endemic such as “ikan bilih” (*Mystacoleucus padangensis*) and some other non-endemic are ikan belingka (*Puntius belingka*), ikan turik (*Cycloscheilichtys*), ikan sasau (*Hampala macrolepidota*). The major concern of fishing activity in this lake is the decline of fish catch however it is not clearly known whether the decline is fish catch is due to overfishing or pollution.

4.5.3 Agriculture

Irrigation of rice fields highly depend on water from the lake. People make use of water for irrigation through water wheel mainly from the outlet of Singkarak Lake from Ombilin River. Intensive rice cultivation (2 – 3 times/year) which is located very close to the bank of the lake is the potential pollutant source particularly from pesticides and fertilizer residue discharge to the lake. Upland farming is also commonly practiced, particularly in eastern Singkarak upland. Farming in this area is a rainfed agriculture characterized by low soil fertility and high potential erosion on steep slopes (Doppler & Bauer, 2001).

4.5.4 Hydroelectric power plant

The HEPP has been operated since 1998, generating 175 megawatts. The power serves the needs of electricity for industry and houses in West Sumatra and Riau Province. Great amount of water are needed to generate electricity through hydrological power plant. In order to maintain water level and supply to the plant, spillway into natural outlet was increased 1 m. Hence, the plant can generate electricity when inflow was decrease. Recently the natural outflow is only 10% whereas 90% is used to operate power plant. The power plant supplies electricity for two provinces namely west Sumatra and Riau province.

4.5.5 Tourism

The beauty and scenic view of the area surrounding the lake make it potential as the tourism spot. Tourism activities include sport fishing, boating, and sightseeing. Moreover, there are some other specific tourism sites surrounding the lake such as Tanjung Mutiara, where visitors can swim or renting boat for touring around the lake. Annual attractive event was held in this lake called Tour de Singkarak which was started since 1999. It is road bicycle racing which involve bikers mostly from Asian countries such as Japan, Malaysia, Singapore, Philippines and Iran. The race covers more than 900 km passing some areas in West Sumatra including Singkarak Lake. One of the main goal of this activity is to promote tourism sites in West Sumatra. However, some more efforts are urgently needed to improve tourism development in this area such as infrastructure, facilities and clean environment.

Some hotels and restaurants are located exactly at the bank of the lake. Most of them do not have drainage system hence all the waste (liquid or solid) flowing or dumped into the lake. Consequently, it becomes potential pollution source contributing to lake pollution. Based on the information from local people, recently the number of visitors which is mainly domestic visitors is getting decrease. The visitors come to enjoy the lake and its beauty only at certain time such as during vocation, ied Mubarak (Islamic celebration) and New Year. Local people argued that this condition relate to the condition of the lake which is dirty and depletion of water quality. Moreover, they do not have enough capital to improve their tourism business.

Emelia (2009) analyzed perception of visitors in Singkarak Lake which are mostly domestic tourists by using survey technique. It is found that majority of visitors concern about the security, cleanliness of environment, lack of other facilities such as proper and clean toilet, place for praying (mosque), etc. Those are things that should be improved by the tourism management in this area hence more people come to visit the lake, not only for stop by or rest area for the travelers (the lake is located adjacent to the main road connecting some cities in west Sumatra and other provinces) but visiting the lake as their destination.

4.6 Land-use surrounding Singkarak Lake

There are eight main land cover types surrounding catchment area including forest, pine, mix garden, agricultural field, rice-field, shrub, grass and settlement or built up area. Major land use in Singkarak Basin is rice field for about 17%, 15% consists of agricultural crops and forest is 15% of the area. 31% of the catchments area is critical land and 30% for other uses (Arifin, 2005). The analysis of land use changes is quantified based on two single land cover maps using the scale 1: 250,000. These two maps were derived from two set Land-sat images which were taken in 1990 and 2002 (Figure 4.6).

From Table 4.5 it can be seen that land cover surrounding Singkarak Lake changed over the period 1990 to 2002 either increasing or decreasing in total area of each land use. During this period, forest, pines, rice fields, shrubs, grass and water body has decreased by 14.67%, 0.22%, 3.03%, 13.44%, 5.18% and 0.25% respectively. On the contrary, agricultural fields, mixed garden, mixed coconut garden and settlement increased by 14.15%, 4.53%, 0.22%, 3.03% and 13.44% respectively. The conversion of forests area into agricultural fields, deforestation and land clearing are among those of factors causing the decrease of forest in this area which is also driven by population growth. Conversion of forests has accelerate erosion rate resulted in land degradation. Based on critical land data of Solok District, erosion rate of Sumani River (one of the main river flowing into Singkarak lake) is 3.02 ton/ha/year. Total erosion rate form its catchment area was found 239 ton/ha/year. Forestry department categorized erosion rate of catchment area in Singkarak Lake into five classes (Table 4.6).

Table 4.5: Estimated Land Use Changes During 1990 – 2002

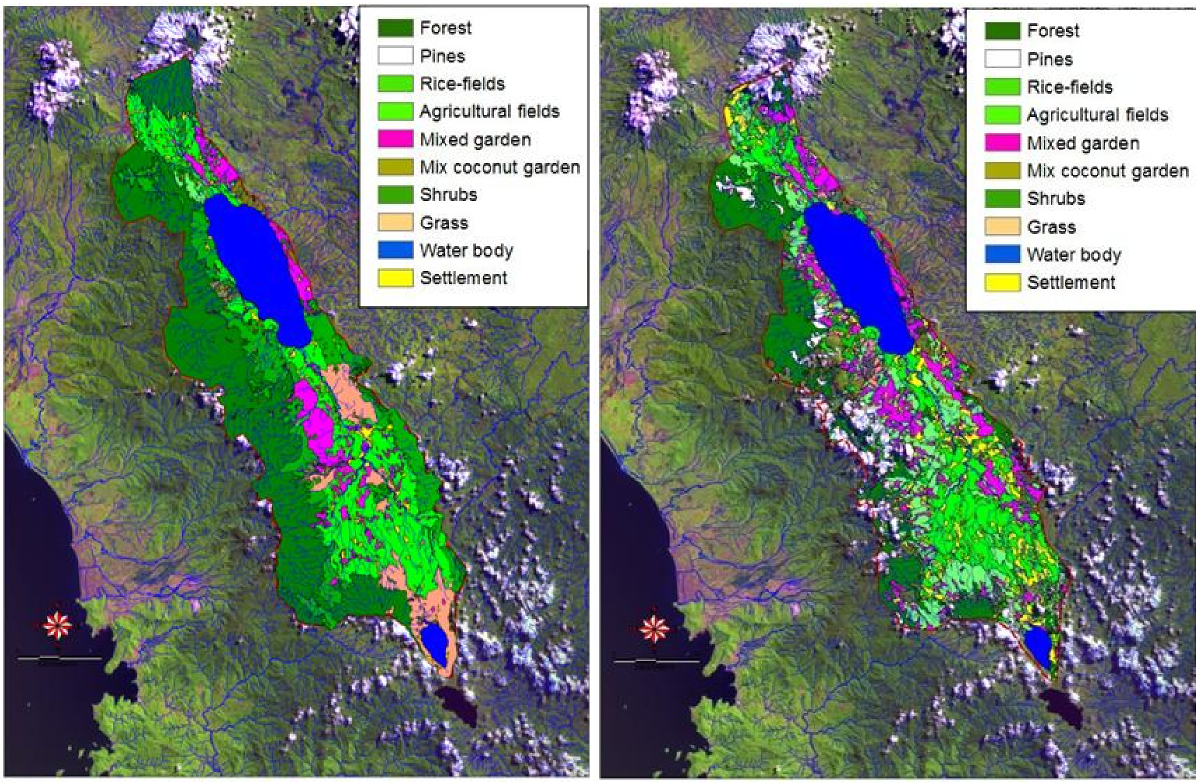
No	Land use	2002		1990		Land use changes (Ha)	
		Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
1	Forest	17,453.76	15.53	33,938.50	30.20	(-)16,484.74	(-)14.67
2	Pines	1,440.47	1.28	1,688.71	1.50	(-) 248.24	(-) 0.22
3	Rice-fields	19,745.49	17.57	23,154.93	20.60	(-) 3,409.44	(-) 3.03
4	Agricultural fields	17,039.34	15.16	1,131.69	1.01	(+)15,907.65	(+)14.15
5	Mixed garden	12,967.34	11.54	7,878.20	7.01	(+) 5,089.14	(+)4.53
6	Mixed coconut garden	5,337.27	4.75	4,659.07	4.15	(+) 678.20	(+)0.6
7	Shrubs	1,665.20	1.48	16,766.54	14.92	(-) 15,101.34	(-)13.44
8	Grass	1,855.16	1.65	7,680.44	6.83	(-) 5,825.28	(-) 5.18
9	Water body (lake)	11,927.71	10.61	12,207.41	10.86	(-) 279.70	(-) 0.25
10	Settlement	9,396.28	8.36	3,271.88	2.91	(+) 6,124.40	(+)5.45
11	Cloud covered	11,358.64	10.11	-	0.00	11,358.64	-
12	Cloud shadow	2,190.71	1.95	-	0.00	2,190.71	-
	Total	112,377.37	100.00	112,377.37	100.00		

Source: analyzed from land use map produced by Department of Water Resource Management of West Sumatra

Table 4.6: Classification of Erosion Rate in Singkarak Catchment Area

No	Erosion rate classification (ton/Ha/year)	Category	Area	
			Ha	%
I	< 15	Very light	62.378	61.89
II	15 – 60	Light	20.775	20.61
III	60 – 180	Moderate	6.409	6.36
IV	180 – 480	Heavy	7.152	7.10
V	> 480	Very heavy	4.079	4.05
	Total		100.793	100.00

Source: Forestry Department: Land Rehabilitation and Conservation Tanah Agam, Kuantan.



Landuse Map 1990

Landuse Map 2002

Source: analyzed from land use map produced by Department of Water Resource Management of West Sumatra

Figure 4.6: Comparison of Land Use Map in 1990 and 2002

The decrease of rice fields' area which mostly located near the lake shore is considered as the conversion of this land into houses or settlement. Some new houses were built at the lake shore that used to be rice fields. This is mainly because of shortage of water for farming. In addition, people built more houses because of population increase requiring more spaces to live in. Shrubs and grass area decreased more compared to other land cover types because most of the people surrounding this area start planting coconut trees and converting to mix garden and agricultural fields in areas where they abandoned. From hydro-meteorological data and information, agro-forestry has been suggested by Subagyono et al. (2008) as the best option to mitigate the impact of land degradation due to erosion. In addition, from recent research by Aflizar et al. (2010) on land-use planning in Sumani watersheds revealed that mix garden, rice fields and reforestation at the bush area were considered to be more effective in controlling soil erosion in Singkarak Lake watersheds.

4.7 Socio-economic, cultural and political background of Singkarak Lake

4.7.1 A brief history of West Sumatra

Based on history of West Sumatra compiled from Hall (1993), Munzinger-Archiv (1990), Scholz (1977, 1988) cited in Gruninger (2001), native population of West Sumatra were specialized collectors, hunters and fishermen. Then farming was introduced by immigrants from South China and Southeast Asian started with cultivation of swamp rice then moved to high land mountainous area. Shifting cultivation, slush and burn farming technique and cultivation of upland rice were types of farming system practiced by the farmers. Land-use intensification was employed due to population pressure. The shift from shifting cultivation and slush and burn into wet-rice cultivation has led to important social changes such as establishment of permanent settlements, land property concepts, households labor division and securing the wives' position due to their ownership of wetland rice.

Merantau (moving to outer areas) has well established since 15^{th} century as the boost. Those conditions are still found in recent times within Minangkabau society including those in Singkarak Lake, which are the centre of early Minangkabau settlement. More than forty years ago, households performed a mixed livelihood strategies with fishing a pivotal activity plus farming and off-farm activity (Scholz 1977 cited in Gruninger 2001). Scholz (1977) stated that "*The Minangkabau as an ethnic group which is always ready to give up traditions and breakup cultural ties if this appears to be economically sensible*". So, adaptation to changing conditions is not new to this social group.

4.7.2 Socio-cultural and political background

People living surrounding Singkarak Lake pose high degree of social homogeneity in terms of their ethnicity and religiosity. Majority of inhabitants in West Sumatra belong to Minangkabau ethnic group and Muslim group. The interaction of community members is regulated by local customs so called *adat* which is further defined as the basis of ethical and legal judgment, social expectation and form the whole value of the system (Abdullah, 1966). Adat also define as "way of life" and can be translated as customs (von Benda-Beckmann & von Benda-Beckmann, 2004). Adat basandi syarak, syarak basandi kitabullah means that all norms, rules, traditional norms and convention enforce in Nagari should be in line with Al-qur'an (holy book of Islam).

Decentralization policies and the promulgation of laws no 22 of 1999 regarding regional government has been taken up particularly by the government of West Sumatra province as the right moment to return to the Nagari. Nagari is "the name of the traditional, pre-colonial political units of Minangkabau". The term used is "return to Nagari" because

Nagari concepts has been implemented in West Sumatra and it has become Minangkabau political identity (von Benda-Beckmann & von Benda-Beckmann, 2001) since colonial period. However, the promulgation of Law no. 5 of 1979 regarding "pemerintahan desa" (village administration) regulate village as the lowest level of local government in every part of Indonesia. Indonesia is a diverse country in terms of its customs and traditions while the main objective of the village administration laws considered as the replacement of diversity with uniformity which has broken down the former unique administrative system including nagari in Minagkabau (Kato, 1989). Therefore, decentralization policies in 1999 has revitalized the role of respected and informal leaders in West Sumatra including within the Nagari surrounding Singkarak lake (Leimona et al., 2006).

In 2000, the provincial government of West Sumatra issued Local Government Regulation No. 9/2000 on the *Nagari Government* System to confirm the role of *nagaris* and their leaders in the local governance system. The *nagari* government is an autonomous local institution led by a mayor (*Wali Nagari)* who is elected at the village level. The village has representatives or a parliamentary body called *Badan Perwakilan Anak Nagari* (BPAN), which consists of *adat* elders *(Ninik Mamak),* religious leaders *(Alim Ulama)* and intellectuals *(Cerdik Pandai).* In addition, two other categories are included, the *adat* women *(Bundo Kanduang)* and the young *(pemuda).* Sometimes BPAN are augmented by local leaders, professionals, farmers' groups, and, rarely, migrants. In addition to BPAN, there are three other elements in Nagari governance namely Kerapatan Adat Nagari (KAN), *Lembaga Penilai/Penasehat Kebijakan* (policy adviser) and *Lembaga Pelaksana Kebijakan* (implementing agency).

West Sumatran people belong to the Minangkabau society, which is characterised by the matrilineal kinship that is embedded into every aspect of this society. Property and land are inherited from mother to daughter. Two types of property rights on natural resources exist, those inherited through matrilineage (called *pusako*) and the village commons (called *ulayat*) (von Benda-Beckmann & von Benda-Beckmann, 2004). One of the most common *pusako* is rice land. The *pusako* system is complex; whether people have *pusako* depends on the family wealth and the sharing of rights amongst lineage members. One hypothesis emerging from the typology is that type I households have *pusako* property rights over their land, whether it is cropped or not (they are older, larger families), while type III households do not have these rights (they are younger, smaller families), which would explain the focus of type III households on fisheries and diversified off-farm activities.

Based upon the *pusako* system, most land lies under the custody of the clan (Ulayat *Kaum)* and the local community (Ulayat *Nagari*), and access rights granted to households are firmly regulated and enforced accordingly. Daily management of *Pusako* rice, its cultivation as well as rights to harvest is granted to women, however man of the lineage (a woman's brother) or lineage head (*panghulu*) play important role in decision making process with regard to all problems related with *pusako* land. The right of a man on his wife's land is vary depend on the family (Kahn, 1976). Husband does not have right to control or make decision over the land but he has right to cultivate the land (if the man is a farmer). Husbands is still benefited even he does not cultivate the land because of the harvest used for family consumption. Despite of the complexes *pusako* system, the existence of *pusako* has supported the lineage members economically. The main function of *pusako* is to provide resources for its member to support their living. However, not all people have *pusako* land depending on the family wealth and their rights within lineage members.

4.7.3 Demographic Characteristics

Based on the data from Indonesian Forestry Department, there are 400,000 people living surrounding Singkarak Lake area and its basin area. The economic activities are mainly agriculture and fishery or combination of both. It is about 76.6% of the people are farmers. Others are fishers and non-farm income activities. Shifting cultivation is also commonly practiced surrounding this lake area. It is estimated that 4.559 families are shifting cultivators. About 10% of population live under poverty line. Total area and population within sub-districts which border to the lake. Those Nagari are belongs to 4 sub districts; X Koto Singkarak and Junjung Sirih (Solok District); Batipuh Selatan and Rambatan (Tanah Datar District). X Koto Singkarak is the largest area surround the lake while the highest population density is in Rambatan sub district.

The study focuses on fishing activities surrounding singkarak Lake. Although fishing is not majority of livelihood activities, small-scale fishers in this area has severely impacted by the declining fish catches. It is hard to find statistical data on exact number of fishers surrounding Singkarak lake. some information are available from statistics of the provincial but lack of detail data about socio-economic of the fishers. Number of fishers compiled from various sources including field survey data for the year of 2009.

Table 4.7: Total Area and Population by Sub-district

No	Sub district	Total area (km^2)	Population			Population density/Km^2
			Male	Female	Total	
1	X Koto Singkarak	295.50	16,330	17,300	33,630	113.81
2	Junjung Sirih	102.50	6,627	7,032	13,659	133.26
3	Batipuh Selatan	82.73	5,320	5,706	11,026	133.28
4	Rambatan	129.15	15,983	17,733	33,716	261.06
	Total	609.88	44,260	47,771	92,031	150.90

Source: Bureau Statistics of Tanah Datar District, Junjung Sirih and X Koto Singkarak Sub-districts (2008)

Based on Idris (2002), the huge decrease of fishers number in Singkarak Lake (more than 50%) caused by the operation of hydroelectric power plant (PLTA). The fishers stop fishing and move to other livelihood option such as farming and laborers. Data from *forum komunikasi masyarakat dan nelayan selingkar danau* (communication forum of fishers and communities surrounding Singkarak Lake) showed that number of fishers in 2000 was increasing (nearly 50%) compare to data from fisheries department of Solok and Tanah Datar. The number of fishers keep increasing until 2003.

Table 4.8: Number of Fishers Surrounding Singkarak Lake

Year	Number of fishers
1995[a]	2046
1996[a]	2069
1997[a]	1913
1998[a]	1354
1999[a]	621
2000[b]	1137
2001[b]	1634
2002[b]	1687
2003[b]	1762
2004[b]	1438
2009[c]	1220

a. fisheries department of Solok and Tanah Datar districts cited in Idris (2002)
b. forum komunikasi masyarakat dan nelayan selingkar danau Singkarak
c. field survey, listing number of fishers from each nagari surrounding the lake (2009)

4.7.4 Economic activities

Agriculture (76.6%) is the main economic activities of people living surrounding Singkarak Lake. This sector has the highest contribution (45.17%) to gross domestic income of Solok district following other sectors such as trading (12.86%), transportation and communication (11.21%), services (10.89%) and other sectors (BPS, 2010a). Fisheries are included in the agriculture sector. Gross domestic income in this area keep increasing from previous years, such as the increment from 2005 to 2008 is about 38%. Solok district is one of the famous rice production called *bareh solok* and the central production of rice in west Sumatra. Although rice production is still increasing which reach 5.8% increment from previous year, this sector is threatened by the rapid conversion of rice fields into other land use. This condition is exacerbated by the increase of population. In addition to rice production, people in Solok District also produce other crops, vegetables and plantation. Livestock rearing is other commonly practice economic activities in this district such as cow, buffalo and poultry. Furthermore, inland fisheries is also part of economic activities in this area which includes open inland fisheries (lakes, reservoir, swamp, etc) and fish farming.

In Tanah Datar district, agriculture also the main gross domestic income which reach 37.77% of the total domestic income in 2009 (BPS, 2010b). It consists of commodity crops such as rice, maize, groundnuts, cassava, sweet potato, soybeans and peanuts. While horticultures include chili, scallion, tomatoes, carrots, eggplant, onion, cabbage, beans, potatoes and many kind of fruits. Other sectors contributing to domestic income are the services (17.12%), trading, hotel and restaurants (12.78%), processing industry (11.75%), etc. similarly, fisheries are included in the agricultural sector. Inland fisheries sector in this Tanah Datar is very potential to develop fish-farming. Some sub district such as Sungai Tarab, Padang Ganting, Lintau Buo Utara dan X koto are the producers of inland fisheries from river and ponds. The main inland fish production are tilapia and goldfish. While Batipuh Selatan sub district is bordered with the lake hence, inland fisheries surrounding this sub-district also harvesting bilih fish from the lake.

4.7.5 Infrastructure and services

Many of the previously constructed road surrounding Singkarak Lake were asphalted, few sub-roads (lanes and paths) within nagari are still being built which connect the remote area to the center of nagari. Most of nagari has local market where people meet and sell their harvesting crops, fish and other basic needs. The market is normally open once in a week (for example, market in nagari paninggahan operates every Thursday, and nagari sumpur's market operates every Tuesday while Nagari muaropingai which is bordered with nagari Paninggahan does not have local market). Some of the fishers or resellers also sell bilih fish in this market. Mobility of sellers or buyers from neighboring nagari is very common during the market day. Regarding electricity, Nagari surrounding Singkarak Lake covered state electricity enterprise (PLN). The need of electricity is rapidly increase and most of the users are households. Households use electricity only for lights and some households appliances such as television and radio meanwhile people are still using kerosene and firewood for cooking. In 2009, there are for about 93.6% of households that have used electricity in Solok district (BPS, 2010a). In Tanah Datar district almost all the *jorong* (village) have electricity service (BPS, 2010b). The use of mobile phone has become very common, even for communication in remote areas. This is made possible due to construction of communication tower from mobile phone service provider.

a b c

Figure 4.7: Nagari's infrastructure (a. asphalted narrow road in the nagari. b. fish reseller in the nagari's market. c. nagari's market)

The most commonly used of means of transportation is motorcycle, rented or owned by the villagers. Few public transportation (minibus) commute from nagari to the city (central of districts). Buses are also available for commuters between districts and provinces from the terminal located in the center of districts. In terms of mobility people surrounding the lake do not have any difficulties although it is more costly and takes more time because they need to travel from nagari to the center of districts by unscheduled public transportation with distance for about 68 km and 72 km to the Solok district capital from nagari muaro pingai and nagari paninggahan, respectively. Other public facilities such as schools and community health center are also available in the sub-districts although the number of higher education is still very less. Junjung Sirih sub-district (Nagari Paninggahan and Nagari Muaropingai) has fourteen elementary schools, two junior high schools but only one senior high school. In Batipuh Selatan sub-district, there are ten elementary schools, four junior high schools and two senior high schools. Therefore, most of the students prefer to continue their study (junior or senior high school level in the capital of the districts). Both sub-districts have only one community health center with limited facilities. Mosques and musholla are easily found in the nagari. There are for about twenty one mosques and ninety five musholla in Batipuh Selatan sub-district, eleven mosques and fifty four musholla are located in Junjung Sirih sub district.

4.7.6 Development Projects

Located between two districts, the second largest lake in Sumatra and unique environmental setting has attracted attention of government and non government organization (local and international) to carry out some development project including conservation and rehabilitation and HEPP project.

4.7.6.1 Singkarak Lake's Hydro Electric Power Plant (HEPP)

The project constructs 175 megawatt (MW) hydropower supplying electricity for industry and houses in West Sumatra and Riau province. The project was conducted by state electricity enterprise with financial aid from Asian Development Bank (ADB). The main components of the project includes a gated weir at the origin of Ombilin river (out flow of the lake), water intake on the western shore of the lake, diversion of intake on the Buluh River, power house cavern with four turbines, headrace tunnel, tailrace tunnel, access roads, adits and other structures. The project diverts water westward of the lake then the water used for power generation in underground power house cavern. This water was discharged to Anai River flowing into Indian Ocean near Padang.

The HEPP has been operated since 1998. Operation of HEPP has caused huge decrease of water outflow through Ombilin River from an average of 51 m^3/s to 2 m^3/s which has impacted upon irrigation, water use for daily needs and riverine fisheries. During data collection, water wheels operated along the river which supply water for irrigating rice-fields have decreased for more than 50% (79 waterwheels) from the year of 2000, previous research conducted by (Febriamansyah et al., 2004), while ADB found more than 100 waterwheels along Ombilin river had damaged. Damaged waterwheels has affected irrigation system of the rice-fields hence decrease rice production. Moreover, operation and maintenance costs of the wheels have also increased because famers have to divert water to the wheels by putting barriers from woods to direct waters towards the wheels. Another strategy adopt by the farmers is by reducing number of water tubes within the wheels so that it becomes lighter and easier to rotate. Moreover, it also increase workloads of the farmers and more operational costs are needed. The decrease of number of waterwheels is given in Table 4.9.

Table 4.9: Number of Waterwheels in Ombilin River (1996 – 2000)

Year	Number of waterwheels	Irrigation service area (Ha)	Number of farmers
1996	366	549	729
1997	296	470	621
1998	237	405	556
1999	195	343	478
2000	184	333	463

Source: Febriamansyah et al (2004)

Operation and maintenance costs of the waterwheels significantly increased due to the damage. Before construction of HEPP, operation and maintenance costs is about 150,000 IDR for each waterwheels. This costs increase into 1,100,000 IDR since the construction of HEPP because they need more labor and capital to fix the damage wheels (Febriamansyah et al., 2004). The process also consume more time thus impact upon their agricultural fields. After HEPP, there are more and more people suffered by the impact including those who stays surrounding the lake and earn their living from lake resources. They are fishermen and riparian communities who use water from the lake for domestic water supply. From an interview with farmers reveals that they cannot afford for operation and maintenance of waterwheels due to very low water level. Some wheels are left abandoned by the owner and they start planting crops instead of rice farming. Domestic water supply and industry were also impacted by the decrease of outflow from Singkarak Lake.

Figure 4.8: Waterwheels for irrigating rice-field in the Ombilin river (outflow of Singkarak Lake)

The most significant impact upon hydropower construction is fisheries sector. Idris (2002) stated that the decrease of bilih fish production after operation of hydro electric power plant is nearly 50%. On the other hands, compensation management did not adequately implemented (ADB, 1999). For instance, delay in payment and low negotiated price for land compensation (land used for sites and access roads). No compensation or programs for fisheries and crops, loss of employment such as fishers and farmers. Limited repairs for the damaged waterwheel along output river, Ombilin due to insufficient water-flow. Mitigation measures should have been implemented appropriately to decrease social, economic and environmental impact of the project. Such in the case of Singkarak lake might also commonly occur in other development project, however communication and consultation is the key process to increase people's participation to identify the interest of affected community which is lacking in Singkarak Lake hydropower project.

4.7.6.2 Rewards for Use of and shared investment in Pro-poor Environmental Services (RUPES) Project

RUPES is a program that develop rewards scheme for environmental service to combat poverty and conserving natural resources. The scheme is integrated into national development planning and varies across nation. RUPES is now being implemented in six pilot sites of three countries namely Indonesia, Philippines and Nepal. RUPES is applied in three sites in Indonesia; biodiversity services in Bungo (Jambi), watershed services in

Sumber Jaya (Lampung) and carbon sequestration services in Singkarak (West Sumatra). This project develops appropriate mechanisms to rewards upland poor people because of environmental services provided which was conducted in 2002 – 2007. The project is funded by international fund for agricultural development (IFAD) and being implemented by World Agro-forestry Center (ICRAF) and local institution partner. RUPES Singkarak project focuses on capacity building of local people through empowerment of local institutions at different scale including nagari level as the lowest government unit with greater responsibility for management of natural resources (Leimona et al., 2006).

The focus of RUPES in Singkarak site is support the provision of carbon sequestration by conserving forests area surrounding the lake, contributing to appropriate land-use management and promoting agro-forestry system to local people to generate carbon sequestration. Based on the issues and problem in Singkarak Lake, the project started to investigate and the analyse the issues through action research. Many perspectives of forests, water and land degradation arise from multiple stakeholders. Through water balance model, local ecological knowledge and local policy discussion, solving the environmental problem in Singkarak Lake could not only rely on reforestation of the grassland instead of combination of reforestation surrounding the lake and electricity generation as well as quantity and quality of water flows. Because construction and operation of hydroelectric power plant has brought major changes on the lake particularly water level of the lake. This initiatives are supported through the creation of enabling institutions by strengthening local, regional and provincial institutions that would support all communities and improve local participation (Leimona et al., 2006).

One of the project objectives is to provides rewards to upland communities through the provision of carbon sequestration in an effort for poverty alleviation. There are four type of rewards listed in this program; (i)flowing the money to the upland communities (creating mechanism of royalties between hydropower producer and local people), (ii)rehabilitation of *hulu* coffee garden (rehabilitation of agro-forestry, water quality and landscape and at the same time improving income of local people), (iii)clean lake program (involving local government from four district to include clean lake program in their activities planning), (iv)rehabilitation of grassland into agro-forestry and establishing education environmental centre (EEC) as the media for sharing knowledge among the stakeholders in terms of lake environment, cultures and tourism in Singkarak lake.

4.7.6.3 Rehabilitation and reforestation projects

Local people surrounding Singkarak Lake have great concerns about the condition of the lake and its catchment area. On the other hands, deforestation by logging company and individual, increasing number of critical land have been an alarming situation. Although the impact of resource degradation is not severely experienced by all local people but some evidences of water quality and quantity degradation, land-slides, river over-flow during rainy season and very dry during dry season. Local people start to do an initiative for rehabilitation of critical land by planting tress which was initiated by leader from Nagari Paninggahan through government project called million trees planting (*penanaman sejuta pohon*). The program was started in 2003. In Singkarak area, the target of the program was to rehabilitate total of 2700 ha critical land within 5 years. In 2004, the program has succeeded to rehabilitate for about 30 – 40 ha critical land (Boer et al., 2004 in Arifin, 2005). The project involve local people by giving seeds of the plant to those who have land and wanted to plant it with various tree species and fruits such as avocado, chocolate and clove. The program is continuously initiated by the government in many parts of Indonesia with various activities such as Indonesia simultaneous planting action (aksi penanaman serentak di Indonesia) in 2007, Women Movement on Tree Planting and Maintenance for Food Security (Gerakan Perempuan Tanam dan Pelihara Ketahanan Pangan) in 2008, One Man One Tree (Satu Orang Satu Pohon) in 2009, One Billion Indonesian Trees (Gerakan Penanaman Satu Milyar Pohon) in 2010. Despite of drawbacks of this program, local people are benefited from the product of the plants and supporting reforestation activities.

4.8 Summary

The main objective of this chapter is to give an overview of Singkarak lake area and its environmental condition, and also a brief introduction to the socio-economic condition of the lake dwellers (Figure 4.9). Those information were mapped and presented in simple DPSIR framework. Response (R) in this framework refer to the existing response of the fishers and regulations implemented by the managers. Those identified responses, particularly response of the fishers are further analyzed in terms of their livelihood characteristics and strategies employed. Since there is a symptom of overfishing, this study discussed the performance of the fishers whether they operate with over-capitalization.

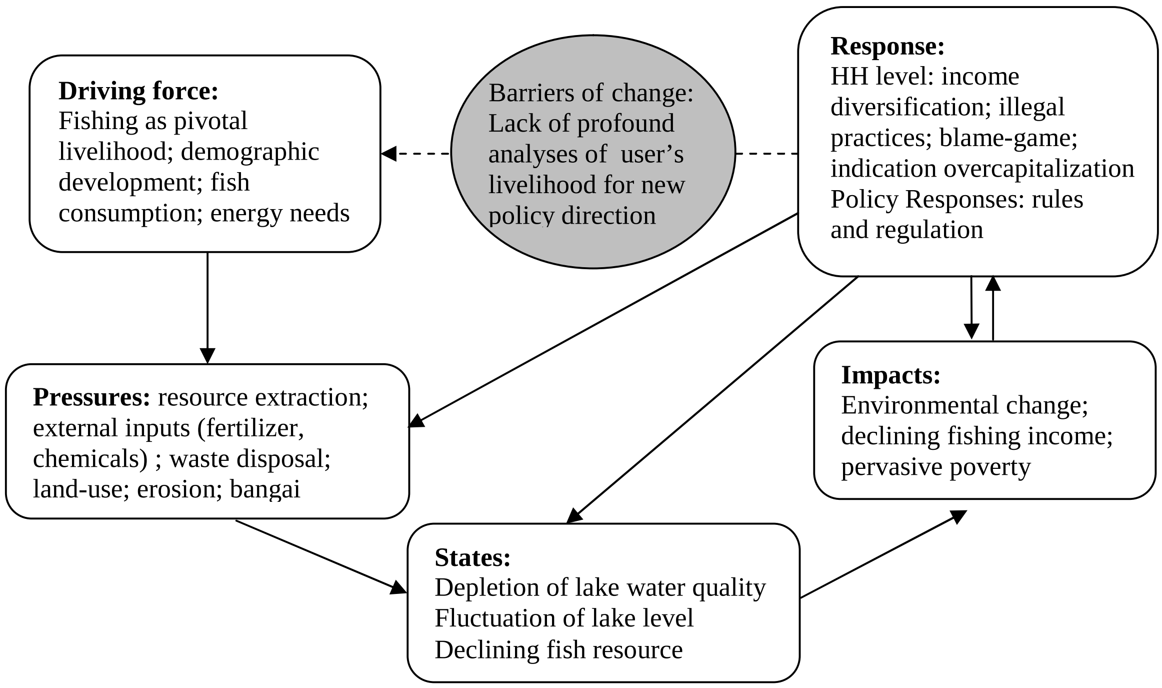


Figure 4.9: Preliminary Analysis of Environmental Issues and Socio-economic Condition

There are five elements discussed in order to frame water quality and quantity problem in Singkarak Lake including driver, pressure, state, impacts and response of water quality and quantity problems. Three main drivers have been considered including population growth, intensive agriculture, and development activities. Those drivers cause pressure on water quality and quantity through waste generated from domestic, agricultural and industrial sources. The current state of water quality and quantity problems is described by the depletion of lake water quality and fluctuation of lake level, and is supported by quantitative data. Water quality depletion potentially causes eutrophication and some other related problems such as nutrients load, distribution of aquatic plants, and phytoplankton. This condition has impacted on the ecosystem leading to declining income of the lake users (mainly small-scale fishers) thus pervasive poverty. Fishers responded to the current condition by employing diverse income sources but fishing is still being practiced. The restriction of net mesh size of fishing gears was implemented by the local government to solve declining bilih fish production.

Further work is required to validate and refine the indicators proposed in DPSIR framework. DPSIR is only as a starting point to understand environmental complex system in Singkarak Lake. A more intensive exploration on socio-economic impact is required so that a more complete picture socio-economic, environmental dynamics and institutional response can be elaborated. For this purpose livelihood characteristics, strategies and diversity of the fishers is also analyzed. Fishers performance in utilizing inputs is presented by technical efficiency analysis.

Chapter 5

Fishery and Fishers Characteristics

Inland fisheries in particular in developing countries rely on diverse ecosystem characteristics and their physical attributes (Smith et al., 2005). This chapters discusses some situational variables of Singkarak Lake's fisheries. The discussion covers two main components namely attributes of resources (biological and physical) and resource users including its beneficiaries. The linkages between the two components are examined through the discussion on the following sub-topic, physical attribute of Singkarak lake, fishing technical attribute, biological attribute, fish landing and marketing, gender role in fishery, major problems of the fishers and current fisheries management practice and possibility for rethinking of an improved management.

5.1 Fishing technical attribute

5.1.1 Types of fishing gear use

Unlike many other fisheries, fisheries in Singkarak Lake use only few types of fishing gears and the fishers use those gears during the year, it is not depend on the season or fluctuation of fish catches. As shown in table 5.1, the most important fishing gears are gillnets (¾, 1 inch of mesh size) followed by cast nets (½, ¾ and 1 inch of mesh size), dragnet and alahan. The most popular method is the use of set gill nets; these nets are fixed into the bottom or at certain distance above it by using anchors or ballasts. Fishermen who only use gill nets would spend for about 6 hours a day on average for fishing and fishing related activities. Fishermen fix the gill net during afternoon and take out from the waters the next day, early in the morning. Some other fishing methods include dragnets and the use of woven wood fibers as fish traps at river inlet points. This method called alahan[4] in local language is only practiced by few numbers of fishers (2%). Different types of gillnets also refer to different targeted fish (bilih, sasau or turik).

Table 5.1: Types of Fishing Gear Used in Singkarak Lake

Types of fishing gear	(% of respondents)
Set gill net (anchored)	39.90
Cast net	29.74
Gill net (sasau)	14.24
Gill net (turik)	7.43
Dragnet	5.97
Alahan	2.09
Others	0.62

There are two types of boat used, both are small wooden boats called biduk. Biduk differ by size and power source. Biduk with paddles are usually 3.5 m long and 0.5 m wide. Biduk with outboard engine power source are a bit bigger, 4 m long and 0.75 m wide. A

[4] Trapping the fish near the meeting point of the lake and rivers drained into the lake by using woven wood fibers as the traps. It is stretch along width of the river.

majority of the fishermen use paddle biduk (71%) and fewer use motor biduk (29%) because of higher capital and operational costs. Fishermen embark on daily short trips, 4-6 hours/day, usually without crew.

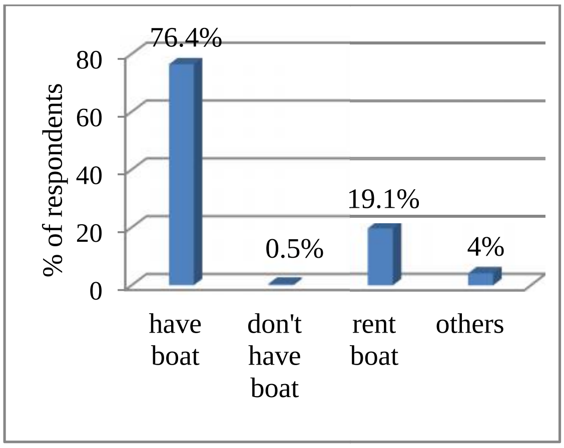


Figure 5.1: Boat Ownership

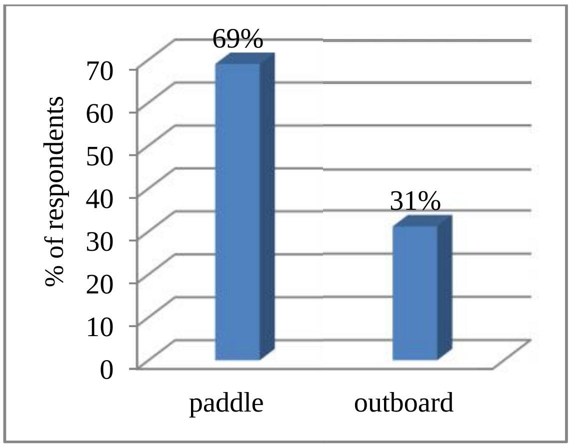
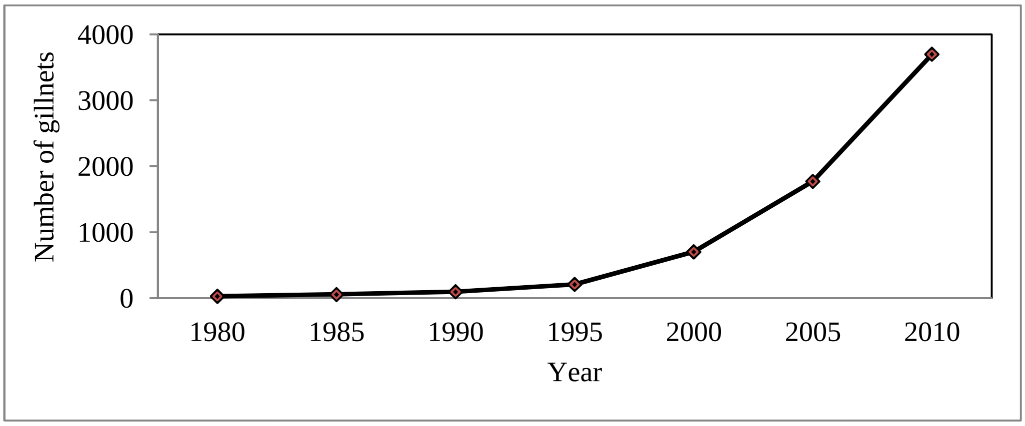


Figure 5.2: Source of Boat's Power

Gillnets are the most popular and dominant fishing gears, which can catch bilih fish even the juvenile depend on the net mesh size. Number of gillnets keep increasing (Figure 5.3). Huge increase of gillnets number occur after the year of 2000. The declining of fish catches has made fishers to increase their efforts indicating overexploitation of the resource. This condition is aggravated by the open nature of inland fisheries in Singkarak lake. Fishers utilize all available efforts to satisfy their personal needs.



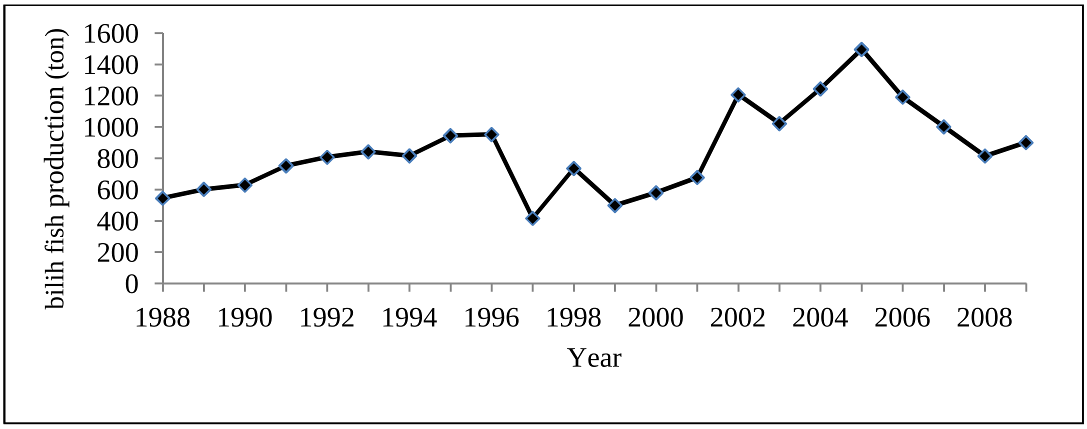
Source: Syandri (2004), Marine affair and fisheries service of West Sumatra

Figure 5.3: Development of Number of Gillnets in Singkarak Lake

5.1.2 Seasonality of fish catches

Fishing in Singkarak Lake is very seasonal in terms of catches which might be influenced by biological, environmental factors and fish exploitation. Fishers recognized there are two main season of fishing which is called *musim banyak* (abundant catches) and *musim sedikit* (scarce catches). Abundant catches usually occur during October to January while scarce catches on February till September. Although there exist seasonality of fish production, fishing is conducted all days through the year using same fishing gears. There is no variation in types of gears used in accordance to seasonality of catches. From focus group discussion with the fishers reveal that currently it is difficult to predict fishing seasons. Sometimes fish catch is declining although they fish during abundant catch season and vice versa.

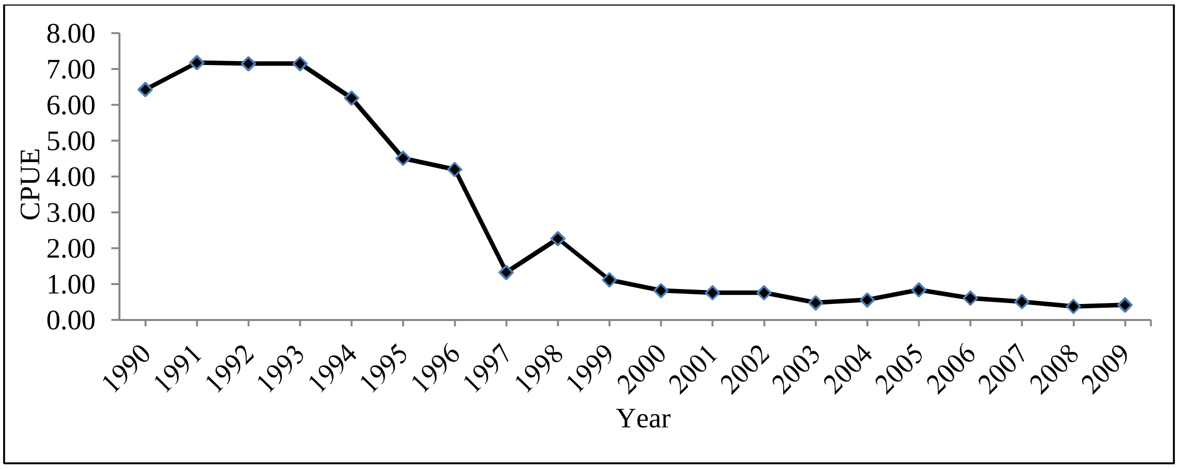
Based on the study about reproduction of bilih fish, Syandri (1996) suggested that fishing of this species should be stopped during January – March because during these months bilih are the spawning time. Spawning is mostly occurring in estuary area which has clear water and shallow. it is believed that this practice could conserve bilih fish population besides creating reservation area for fish spawning. However, the fishers keep fishing all days by using more efforts (set up more gillnets to get more fish).



Source: Marine affairs and fishery services of West Sumatra, Kabupaten Solok dalam angka, Kabupaten Tanah Datar dalam angka

Figure 5.4: Annual Average Catch Rate of Bilih Fish (Ton)

Figure 5.4 shows total annual bilih fish production from 1988 to 2009. Fish catches is gradually increase. However, significant decrease of catches occur in 1997 with a plunge between 1996 to 1997 more than 50%. The huge decrease of bilih production is mainly caused by the use of fishing gear with small net size and overexploitation (Syandri, 2004). While fishers argue that decline of catch is mainly caused by the operation of hydroelectric power plan and depletion water quality. Although they also realize ill-fishing practices is fairly common. After 1996 until recently, annual average catch rate continue to fluctuate in significant number. In addition to natural calamity (bangai) exist in the lake, various reason of fluctuation are mentioned such as degraded water quality, overfishing, unsustainable fishing practices, and construction and operation of hydroelectric power plant.



Source: Syandri (2004), Marine affair and fisheries service of West Sumatra

Figure 5.5: Catch per Unit Effort (CPUE)

In addition to seasonality of catch, catch per unit effort of bilih fish keep decreasing which indicates biological overfishing. Figure 5.5 Illustrate time series data of fish catch in comparison with number of fishing gears (in this case number of gillnets) for the year 1990 – 2009. A number of threats to fish resource have been identified, and they include overfishing, water pollution, competition with exogenous species, and deforestation that leads to erosion and siltation (Arifin, 2005; Arsil, 1999; Berkademi, 2011; Farida et al., 2005; Syandri, 1996). However, most sources concur that overfishing is the primary cause of resource decline. The sources also shows that the primary commercial indigenous species (*Ikan bilih*, *Mystacoleucus Padangensis*) is economically overfished (Arsil, 1999; Berkademi, 2011), which means that the livelihoods of fishing communities are severely affected by declining catches.

5.2 Biological attribute

5.2.1 Biodiversity of fish resource

Singkarak Lake has diverse fish species including ikan turik (Cyclocheilichthys de-Zwaani), belingka/kepiat (Puntius belinka Blkr), garing (Labeobarbus spp), sasau (Hampala macrolepidota), asang/paweh (Ostechilus hasselti CV), tilan (Mastocembulus maculates CV), balindang, mujair (Oreochromis), nila (Tilapia), bunta, baung (Mystus) and malingka. However, recently the main catches is the endemic species, bilih fish (Mystacoleucus padangensis). The catches of this species reach more than 85 – 90% of the total catches (Purnomo et al., 2003a).

Some important aquatic plants found in Singkarak Lake ecosystem are *Azola pinata, Antruontera philoxeroides, Chara filerose, Cyperus sp, Eichornia crassipes, Hydrilla verticilata, Ipomea aquatica, Jessena repens, Lemna sp, Leersia hexandra, Nelumbo nucifera, Potamogeton oblongus, Pistia stratiotes, Pygonim barbatum and Panicum repens* (Puslitbang Pengairan 1986, Biotrop 1983, Unsri 1983 in Sulastri & Harsono, 1994).

Table 5.2: Types of phytoplankton in Singkarak Lake

Chlorophyta	Actinastrum, chlorella, cosmarium, dictyosphaerium, kirchneriella, oocyctis, scenedesmus, staurastrum, tetrahedron,
Cyanophyta	Anabaena, chroococcus, merismopedia, microcystis, spirulina
Chrysophyta	Navicula, surirella, synedra
Pyrrophyta	Peridinium
Euglenophyta	Euglena

Source: Sulawesty et al (2002)

The most abundance of phytoplankton are cosmarium, dictyosphaerium and staurastrum, anabaena, synedra and navicula. Among those commonly found phytoplankton, anabaena and synedra are the highest abundance. The presence of anabaena is harmful, particularly if blooming occurs because it produces neurotoxin (Sulawesty et al., 2002).

Lots of biological bilih fish research have been conducted in this area by scholars and researchers from various institutions. Such as reproduction of bilih fish and possibility of its breeding (Syandri, 1996), analysis of phytoplankton abundance (Maiyarni, 1997), factors influence the endurance of eggs of bilih fish (Fauzi, 1995; Juita, 1995) and also fecundity of bilih fish (Patriono et al., 2010). Establishment of conservation area as the breeding area for bilih fish is highly recommended to conserve bilih fish and stock enhancement (Purnomo et al., 2003b). however, these efforts were lack of support and monitoring from the local government hence most of the conservation ares are no longer available. Only in some places in Nagari sumpur which still maintain conservation areas and strictly banned fishing in this area.

5.2.2 Fishing grounds

In Singkarak Lake, fishers operate in the lake and reservoirs or rivers drained into the lake. Usually they operate in the lake side nearby their house. Fishers using gillnets are mostly concentrated within 0.5 – 3 km of the lake shore. Whereas fishers using dragnets mostly do fishing at the edge of the lake and at the inlet river points. Most fishers use the same fishing grounds and territories even there is seasonality of catches. They will not move to other fishing ground in other nagari because there is fishers wise rule that fishers do fishing in their home nagari. It is also possible to do fishing in his wife's nagari because after marriage Minangkabau man usually stay with wife's family before they are able to build their own house.

5.2.3 Perception of fishers on fisheries resource condition

From focus group discussion fishers shared their view about the current condition of fisheries resources. This perception is substantiate from household survey. Fishers were asked about their opinion on the current condition of fisheries in the lake. Almost all fishers (95%) stated that the fisheries resource is getting decrease (Figure 5.6). The fishers conclude this from the declining bilih catch and extinction of particular species. Therefore, fishers' level of satisfaction is low (82.5%) and 16% of the fishers shows middle level of satisfaction (Figure 5.7). Supporting the findings from Fabinyi (2010), fishers in Singkarak lake are continuing to fish despite significant decline of profits, they continue fishing. Most fishers state that they need to fish whenever possible (even they have to allocate longer time for fishing) to sustain their income for the fulfillment of basic family needs.

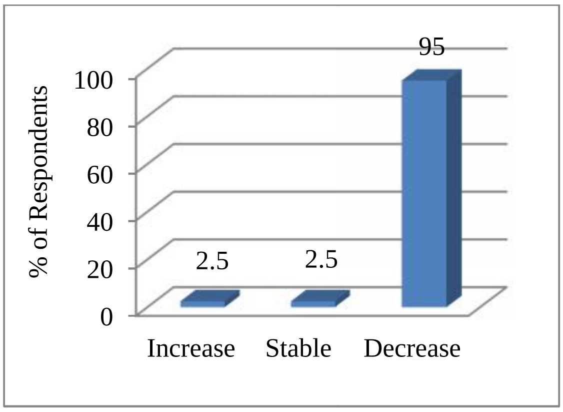


Figure 5.6: Perception of Fishers on Current Fisheries Resources

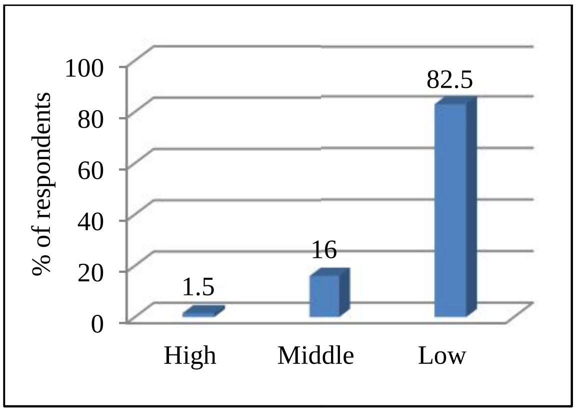


Figure 5.7: Satisfaction Level of Fishers on Current Fisheries Resources

5.2.4 Perception of fishers on causes of declining fish resource

Vast number of fishermen (94%) perceives that their income has decreased due to the decline of resource condition. Likewise, fluctuation on resource abundance is another problem faced by fishing communities although they realize that it has been occurred some years before. "*Life is getting complicated now, it's so hard to get even 2 liters*[5] *of fish per day, before we even can spend whole day to take out the fish from the nets and need more workers and we can identify which month of the years we got less catch and time when we could get abundance fish but now it is very difficult to predict*" – interview, Agus – interview, August 2009. Current weekly fish catch has significantly decreased compared to 5 years ago, which is 111.94 liter to 48.74 liter in average.

There are various reasons described by the fishermen as the cause of fisheries resource condition including construction of HEPP, water quality and quantity decline, the use of destructive fishing gears (small net size, explosive and poisonous materials), lack of coordination, law enforcement and the absence of fish trading agency (Table 5.3). Among those causes, construction and operation of hydro electric power plant and the use of explosive, poisonous materials highly contribute to the decline of resource condition. Likewise, water quality and quantity exacerbating fish resource. In general, the causes of fisheries decline are perceived at the high and medium level of WAI. However, t-test shows significant different between male and female for some causes which also depicts the two groups have different perception on this issue. The perception of male and female "decrease of water quality and quantity of the lake as the causes of fisheries decline" is significantly different although both groups have high level of WAI. Male group have stronger support to this statement than female group. Male interact more often with lake than female because male do fishing at the lake and they spend more time in lake. They also pointed out that lots of rubbish deposited at the bottom of the lake which often trapped into their gears. On the other hands, female only involve in fishing related activities such

[5] Fishermen use a measured cup equal to 1 liter volume; 1 liter = 0.8 kg (for fresh *bilih* fish)

as harvesting the fish, selling and fish processing which mostly done at the ground. Although female use lake water for domestic purpose such as washing and bathing, it is only at the edge of the lake and its surrounding area.

Table 5.3: Perception Towards Causes of Declining Fisheries Resource

Causes of fisheries resource decline	Male		Female		T- test	Significant
	WAI	MC	WAI	MC		
Decrease of water quality & quantity of the lake and its surrounding	0.905	HM	0.799	HM	3.407	0.000*
Construction and operation of HEPP	0.917	HM	0.816	HM	3.215	0.000*
Use of fishing gear with small net size	0.724	HM	0.616	MM	2.648	0.919
Use of explosive, poisonous materials	0.922	HM	0.805	HM	3.602	0.000*
Lack of socialization of rules/ regulation to fishing community	0.787	HM	0.634	MM	4.254	0.894
Weak law enforcement	0.796	HM	0.634	MM	4.448	0.110
Lack of coordination between government and fishing community	0.771	HM	0.673	MM	2.676	0.017*
Absence of particular agency to manage fish marketing, trading, etc	0.767	HM	0.706	HM	1.637	0.334

Note: MC = magnitude of cause; LM = low magnitude = 0.1 – 0.33; MM = moderate magnitude = 0.34 – 0.67; HM = high magnitude = 0.68 – 1

Significant different is also shown by construction of HEPP, use of explosive and poisonous materials as the causes of fisheries decline although both groups have high level of WAI. For both causes, male group have stronger support than female group. Female group have less knowledge on the construction process of HEPP and its cause effect relationship to the lake ecosystem. An evaluation of the project was conducted by ADB (1999) and found that participation of affected person during HEPP project preparation and implementation is quantified as poor (scale: very good, good, satisfactory, poor) in terms of consultation and decision making process. Consultation and decision making process mostly involved male elder respected person and some representatives from fishermen. Lack of coordination between government and fishing community is also mentioned as one of the factor contributing to the decline of fisheries resource. It shows significant different between male and female group with high and medium level of WAI for both groups respectively. The existing gender divisions in within fishing community in this area, male have been fishers and female in charge of fish processing, care taker, maintaining family and kinship could be the a constraint for female groups to participate in fishing group meeting where people share knowledge and information.

5.3 Fish landing and marketing

5.3.1 Utilization of fish catch

Fishers wise fish landing center has established along the bank of the lake where the fishers harvesting their fish from the nets and sell their catch to middlemen or consumers (mostly villagers who buy the fish from the fishers).

Fisheries contribute to main income for the family and secure family's food supply because most of the fishers do fishing for both consumption and selling purposes. Figure 5.8 shows percentage of utilization of fish catches. About 79% of the fishers use their catch for consumption and selling with much bigger portion for selling.

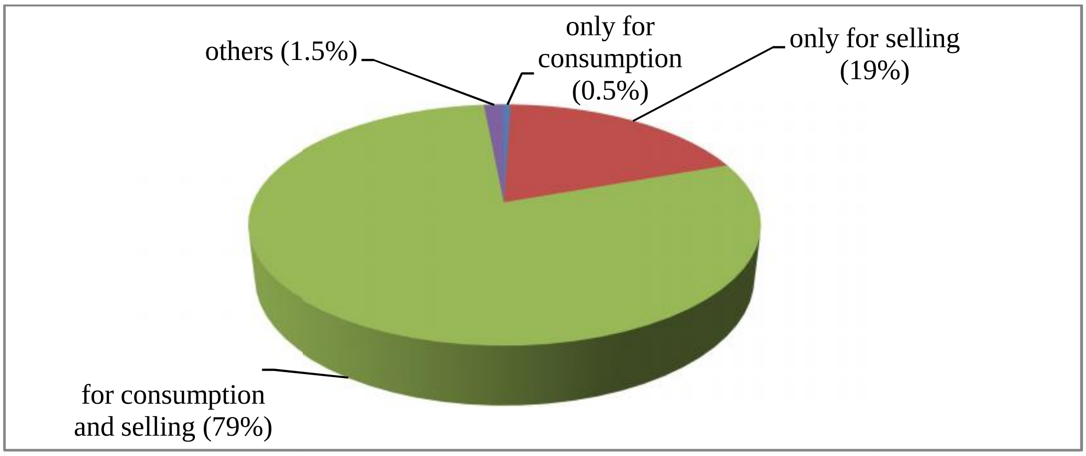


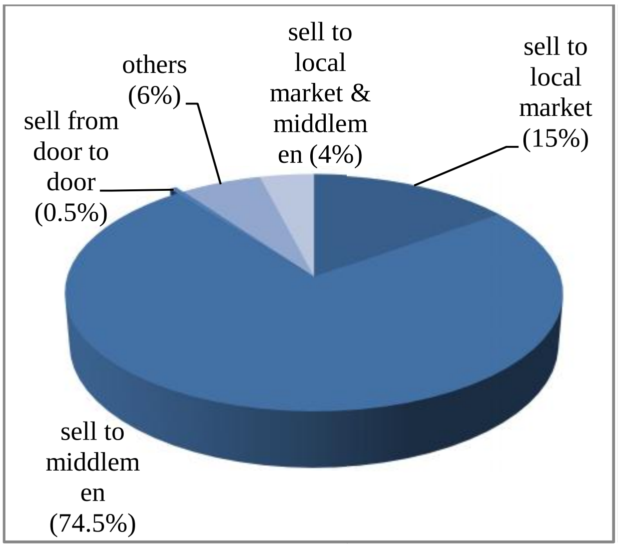
Figure 5.8: Utilization of Fish Catches

5.3.2 Fish marketing system

Like in many other small-scale fishing communities in developing countries, the traditional fish marketing system characterized by weak bargaining power of the fishers (Pizzali, 1988). The fishers landed their catches on the scattered beaches, the fish traders financed most of marketing activities. Sometimes the traders also function as source of informal credits, providing cash for fishers' family needs particularly during the scarce catch.

Most of the fishers sell their catch to middlemen (74.5%), about 15% sell their catch to local market and in few number sell to both local market and middlemen (4%). Some of the middle are from same nagari but some of them are from other nagari, particularly from Ombilin which is the center of bilih fish processing and selling. The middlemen can be categorized as big-scale and small-scale based on the amount of fish purchased. Small-scale middlemen usually buy fish in small amount for about 10 – 20 kg while big scale middlemen can buy as much as fish offered by the fishers. The fishers sell their fish directly to the market or consumers. Big-scale middlemen sell their fish to the fish processing industry (home industry), to the souvenir shops in nagari Ombilin and supplies to restaurants. They sell both fresh fish or the fish that has been processed into fried, boiled or dried fish.

The fishers complaining about their weak position in price determination. This condition encourage the fishers to catch fish as much as they can catch so their income enough for subsistence. The findings from Oduro-Otieno (1978) report that the small-scale fishers tend to be “price-takers” rather than “price-makers” in the absence of strong cooperative and lack of refrigeration facilities. Geheb (1997) confirmed that this condition encourage fishers for intensification in fishing to maintain their income.



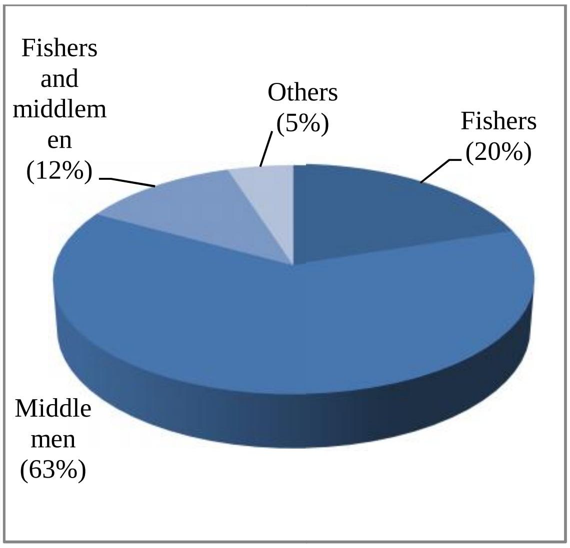


Figure 5.9: Selling of fish catches **Figure 5.10: Determination of fish price**

The fishers agreed that bilih fish sell on local scale which made up majority of the consumption. In addition, bilih fish is also sold in other cities and provinces. Fish marketing system are done on cash basis and there is no certain contract between fishers and middlemen. Sometimes middlemen give money after they sell the fish in the market. The middlemen usually sell the fish within the nagari, other nagari or even other neighboring cities such as Bukittingi, Padangpanjang, Solok and Padang city. Middlemen with greater capital usually give the money to fishers during fish transaction. Fish price are dominantly determined by middlemen though some fishers mentioned that fish price is determined by the fishers (20%). Some other practice is negotiation between fishers and middlemen.

Figure 5.11 Shows complete picture of fish marketing system in Singkarak Lake. The fishers can sell their catch directly to the consumers (households, home industry) instead selling the fish to the middlemen. However, the fishers prefer to sell their fish to middlemen because the middlemen go and collect the fish from the fishers directly hence save time and fishers do not need to transport the fish to consumers.

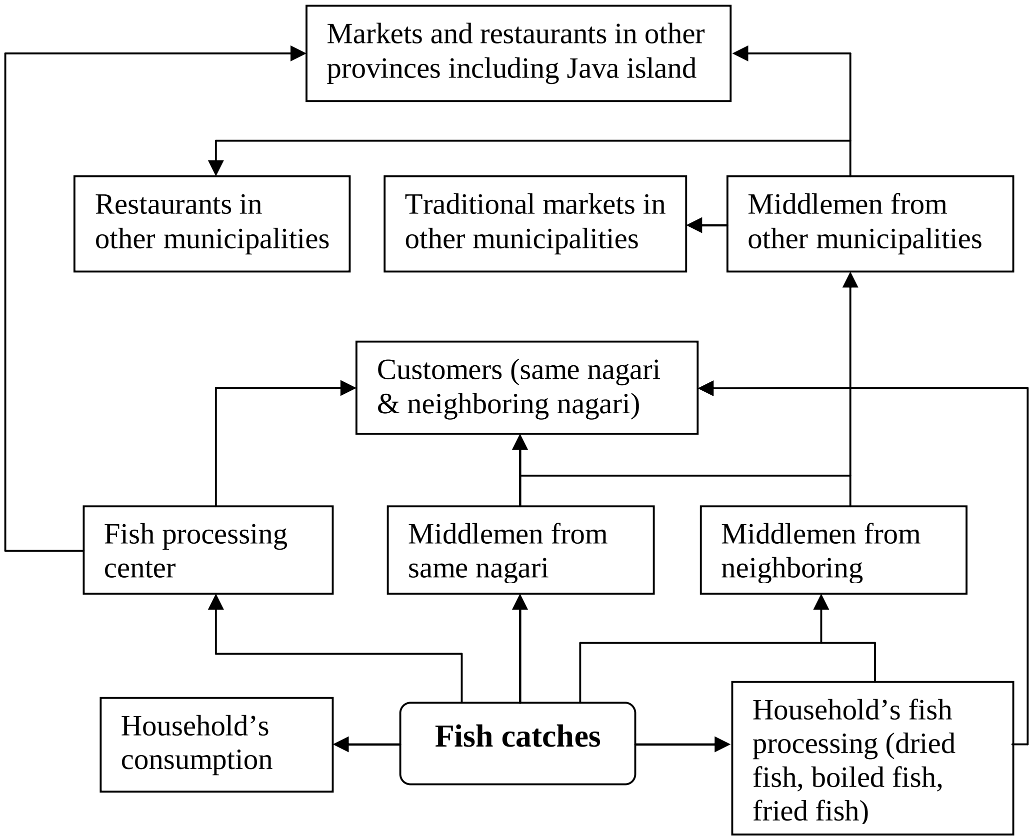


Figure 5.11: Bilih Fish Marketing System

In terms of bilih fish demand, more than half of the fishers (Figure 5.12) state that the demand has changed during last few years. The pattern of the decrease shows the decreasing demand. The fishers argue that the decreasing demand is mainly caused by the bilih fish from Toba Lake, North Sumatra. Although bilih is the endemic species, the breeding of this fish in Toba Lake in 2003 has been successful. Toba Lake was chosen as the other place for bilih fish breeding to conserve the fish from extinction. Characteristic of Toba and Singkarak Lake is almost the same in terms of clear water, low water temperature and sandy seabed (Purnomo et al. 2003a, Sarnita and Kartamihardja 2003 cited in Kartamihardja and Purnomo 2006). In 2005, total catch of bilih fish in Toba lake was 653.6 ton with 10.5 – 15 cm in length and 8 – 30 gram weight. This size is bigger than bilih fish cath in Singkarak lake which is about 4.5 – 8 cm in length (Purnomo & Kartamihardja, 2006). The price of bilih fish from Toba Lake is also cheaper than bilih in Singkarak Lake. In 2005, the price of fresh bilih from Toba lake is 5,000 – 8,000 IDR per kg and dried bilih fish is 16,000 – 20,000 IDR per kg which is cheaper than bilh from Singkarak Lake which is 12,000 – 15,000 IDR per kg for fresh bilih and 40,000 – 60,000 IDR per kg for the dried fish. Based on the discussion with fishers in Singkarak Lake, the price of the fish also fluctuate depend on the abundance of the fish catch. The fishers usually sell the fish in the price range 6,000 – 25,000 IDR per kg. The fishers complained about the bilih fish from Toba lake sold in cheaper price than bilih from Singkarak. From the interview reveals that the fishers wish the government to limit or ban bilih from Toba so that the price is better and more stable. Moreover, the fishers expect the local government give support by establishing fisher's organization which is able to manage fish price and provide access to credit facilities.

Because of the decreasing bilih catch from Singkarak Lake and the lower price of bilih from Toba Lake, the middlemen and home industry order the fish from Toba Lake. It takes for about 16 hours by car to transport the fish. In terms of taste of the fish, Singkarak lake community argue that the taste of fish from Singkaraka is more delicious than bilih from Toba lake. However, most of consumers cannot differentiate the fish whether from Singkarak or Toba. More and more bilih from Toba lake enter bilih market in Singkarak and surrounding area. The fishers face new problem because they have to compete with bilih from Toba lake. The consumers tend to choose cheaper fish although the quality and taste is lower. As the consequence, the fishers have to sell their fish with lower price.

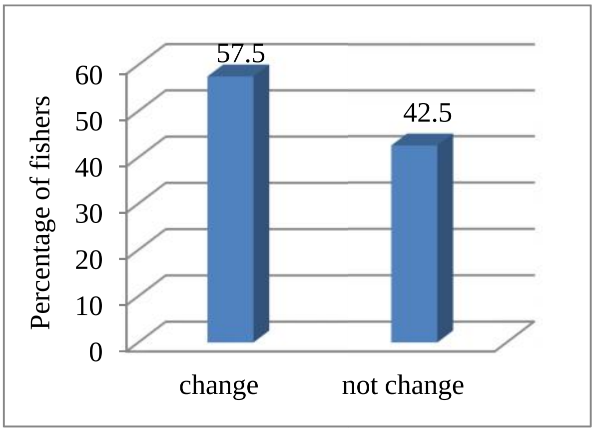


Figure 5.12: Changes of Bilih Fish Demand

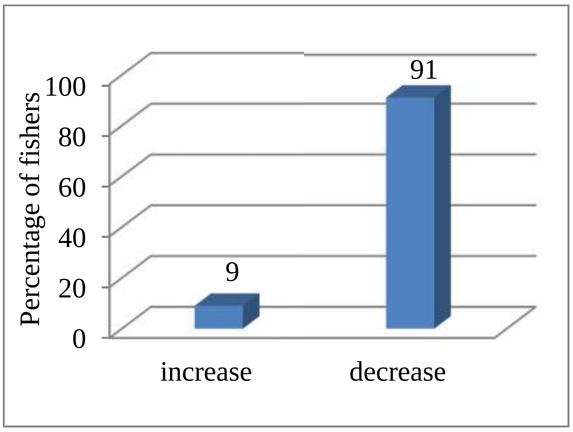


Figure 5.13: Pattern of Changes of Fish Demand

5.4 Gender role in fishery

From focus group discussions with fishers, revealed that fishing is being practiced as both a tradition and a family business. Most people start fishing with parents or sometimes alone when they are very young (8 – 15 years old). In most households, all members are involved in income generating activities such as fishing, farming or nonfarm income activities, yet in most cases fishing is only a part time activities for kids. Labor division varies according to the livelihoods strategies employed and number of household members.

Men usually go for fishing alone and women contribute to fishing related activities such as collecting fish from the net, fish processing (cleaning, packaging in hand-made baskets with ice before transport to market) and marketing. Women do not go for fishing, instead they usually wait for their husband coming back from the lake taking out the gillnets. Women tasks are collecting fish from the net, fish processing (cleaning, packaging in hand-made baskets with ice before transport to market) and marketing.

Table 5.4: Daily Fishing Activities and Time Allocation Before and After Declining Fish Catch

Activities	Duration (hours/person/day)		Who did the task			
	Before declining	After declining	Men	Women	Men	Women
			Before declining		After declining	
Preparing gear and fixing the nets at the certain distance	3	2	√	√	√	
Take out the nets from the lake	4	2	√	√	√	√
Harvesting the fish	5	2	√	√	√	√
Scaling, selling	2	1		√		√
Fish processing (if any), marketing	6	4	√	√		√

Table 5.4 shows the decrease of working hours for both men and women before decline fish catch (before 1998) and after declining of fish catch (1998 – now). Recent time allocation for fishing activities is less compared before declining fish catch. Particularly time spend for harvesting fish from net. Before it took for about 5 hours and women are the main labor whereas after declining of fish catch, it takes only for about two hours to do this task. The same trend happens for other type of fishing related activities. Women were also involved in preparing gear and its maintenance but recently women do not do this task because of less fishing gears used. For the households who also engage in fish processing, more labor were needed including men (either husband or son). However, less fish require less labor for processing, wife and daughters are the main labor for this task. The notions of men do fishing at sea, lake or others on boats and women stay home as the caretaker is still embedded in Singkarak Lake fishing community although some finding other studies have found that women have turned over by becoming fishers as an adaptation strategy (Munk-Madsen, 2000).

5.5 Current management

Identifying the knowledge of the fishers about the current management measures is necessary to assess implementation of rules and regulations. Table 5.5 shows fishers knowledge concerning rules and regulations implemented in this fishing area. The fishers are aware and know about some restrictions which is shown by high level of weighted average index for all listed rules. Some of these rules are written in the big board near the lake such as the restricted area for fishing in the conservation zone. The concerns of fish depletion has been formulated through those rules and understood by most of the fishers, however the implementation is still being questioned. This reveals from the fishing practices which mostly use net mesh size smaller than 1 inch (3/4, ½ inch) and other unsustainable fishing practices such as the use of explosive and poisonous chemical are still exist particularly in the nagari that do not have specific rules for fishing. In this case, the lack of knowledge, endorsement or/and enforcement of such regulations by local authorities (*nagaris*) does not help to solve the resource decline issue; it merely confirms and reassures fishermen in their denial of any wrongdoing and their potential role in resource decline. Weak local fisheries governance and weak enforcement of rules and regulations in fishing at the local level has proven to be one of the causes of declining fishing profits of small-scale fishers in the Mekong river basin (Navy & Bhattarai, 2009). On the contrary, collective actions of inland fishing communities in Sri Lanka regarding restriction of minimum net size and amount of fishing effort have been effectively implemented and the rate of resource exploitation was not evident (Amarasinghe & De Silva, 1999).

Table 5.5: Fishers' Knowledge on the Current Fisheries Management Measures

Rules and regulations	WAI	LK
Using net mesh size not smaller than 1 inch	0.774	HL
Prohibition of using explosive material for fishing (Law no. 31 of 2004	0.964	HL
Prohibition of using poisonous and harmful chemical (Law no. 31 of 2004)	0.967	HL
Restricted area for fishing surround conservation area	0.896	HL

Note: LK = Level of Knowledge; 0.10 – 0.33 = Low Level (LL); 0.34 – 0.66 (ML); 0.67 – 1.0 = High Level (HL)

Each *nagari* government governs and enforces the norms and conventions "for the sake of a prosperous society in Singkarak area". One of the sampled nagari which has well implemented rules and convention fishing is Nagari Sumpur. This nagari has specific norms and conventions for fishing along the inlet river. It is called "perna" (peraturan nagari) or Nagari's rule number 3 of 2004 regarding norms for fishing in Nagari Sumpur. It contains detail instructions, prohibitions and sanctions of fishing practices including fishing gears, fishing areas, fishing time and rules of fishing for fishers from other nagari (Appendix). Interview with head of nagari, nagari officer, and adat leaders reveal that the fishers commit with the rules although in some cases fishers break the rules. In this case, the fishers also obey all the sanctions imposed due to his ignorance. One of the widely implemented sanction is paying the fine of 5 sacks cement which will be used for construction of public facilities within the nagari. Informal rules within the *nagari* system are usually well-defined and enforced, and civil society in Singkarak is generally aware of formal rules enforced by the state. This enforcement does not seem to exist for state-originated, official, administrative regulations unless it is well implemented at the nagari level in the form of rules or norms. As in many other community based fisheries management system, monitoring and rules enforcement are commenced by resources users themselves (Ruddle, 1994). The implementation of rules and norms at the nagari level is closely monitored not only by the nagari official but also the community. Local respected adat leaders also play important role in the implementation of rules and norms at nagari level. Those who violate the rules not only have to bear economic sanction (pay some amount of fines) but also social sanction (banned to do fishing in certain period of time, shaming, etc.). In addition, fishers who ignore nagari's rule will also be invoked by customary law (*hukum adat*).

These regulations are largely ignored by local fishers partly due to fish scarcity and economic pressure. Traditional institutional arrangements and regulations under the *nagaris* have yet to integrate rapid evolutions at play (Arifin, 2005), first in acknowledging the issues faced and second in implementing and enforcing existing, adapted or new regulations. Central or provincial government should have been able to create good coordination hence nagari which is the lowest level of governance work in hand to support implementation of rules and regulations. Community realize the importance of their involvement in decision-making process which is important basis for community based resource management. Table 5.6 shows the perception of fishers concerning their involvement in fisheries management through decision-making process, the importance of their involvement and responsibility of resource management. More than fifty percent of the fishers agreed that fishers' representative and commission were involved in decision-making process. The representative of fishers group brings all the needs and aspiration of the group members after having group discussion which mostly occur during their spare time while fishing. The fishers also realize the importance of community participation in decision-making process hence an improved fisheries management should be role-sharing between government and local people. Promoting active participation between communities, interests group and government in the management of inland fisheries could be an option to cope with open access inland fisheries and the underlying issues (Hossain et al., 2006). In the decision-making process should eliminate the gap between decision-makers, decision-makers, the system (resources and local people) to be governed and the governing system hence the community can be part of the process (Onyango, 2011b). It enables decision-makers to understand the values, norms, and local knowledge.

Table 5.6: Fishers' Perception on Community Participation in Fisheries Management

Community involvement in fisheries management	Frequency	Percentage
1. Who involve in decision-making process of fisheries management at nagari level?		
- Only nagari's commission	33	16.5
- Nagaris's commission and representative of fishers group	105	52.5
- Elder respected people and fishermen group	27	13.5
- Others	35	17.5
2. How do you rate the importance of community participation in formulating the rules		
- Important	180	90
- Neutral important	18	9
- Unimportant	2	1
3. Who should be responsible for fisheries management		
- Government (central)	38	19
- Community	9	4.5
- Sharing cooperation between government and community	138	69
- More role of central government than local government	7	7
- More role of local government than central government	8	8

The lake itself is considered a common-pool resource that is shared among riparian *Nagaris*. Although *nagaris* typically establish and enforce clear regulations on natural resource management under their jurisdiction, specific local regulations on fisheries with regards to the sharp resource decline do not seem to currently exist. Administrative regulations on fishing net mesh size are not enforced by all *nagaris* or provincial authorities. No specific institutional setting exists for catch fisheries. The fact that fishing activities are typically performed and managed by men excludes them naturally from the *pusako* system. Although the category of open access is acknowledged, it is trivial and interpreted in many ways (Arifin, 2005). Lake water and other hydrologic systems related to the water networks are considered common property for fishing, irrigation, aquaculture and other life-support activities. Any riparian dweller may currently fish or use the lake (for domestic or recreation purposes) at will.

5.6 Summary

This chapter analyzed the socio-ecological system of the Singkarak Lake in Sumatra from multiple angles: technical, socio-economic, and institutional. Characteristics of small-scale fisheries collected in this study is similar in nature with other small-scale fisheries particularly in developing countries. It is multi-gear fishing practice (Farrugio et al., 1993); using low level capital and technology (Sowman, 2006); mostly use small non-motorized vessels (FAO, 1995; Kent, 1997); targeted multi species, though recently fishers in Singkarak Lake mainly catch bilih due to scarcity of some fish species. Like in many other fisheries, fish catch is highly fluctuated and declining. It is economically overfished (Berkademi, 2011).

While all parties confirm the decline of the fish resource, they have different diagnoses to explain the causes. In particular, experts and scientists point out overfishing and unsustainable (and illegal) fishing practices, while fishers allude to water quality decline and increased competition between uses, including hydropower. Although the chapter does not provide its own diagnosis, it notes that existing regulations on net mesh size are not implemented nor enforced. The mere fact that such regulations exist shows that provincial authorities do recognize the issue and the need for more sustainable fishing practices. However, local traditional authorities (*nagaris*) and the fishers themselves have yet to come to terms with the role played by fishing practices in the issue. Institutional analysis shows that *nagaris* have the jurisdiction and the potential power to set up, implement and enforce adapted regulations towards more sustainable fishing practices. Involving fishermen groups and making them come to terms with own unsustainable practices and their role in fish resource decline is the challenge to be met. Clearly defined roles and responsibilities of communities through local organizations, local leaders in fisheries management. This must be done urgently, in view of the sharp decline in fish catches. Moreover, Nagari’s rules and norms not only transform governments law or regulations into practices but it is also rich of local knowledge and customary law. Strengthening and facilitating the existing community-based fisheries management would be a potential option to an improved and sustainable fisheries management.

Chapter 6

Livelihood Systems and Strategies of Singkarak Lake's Small-scale Fishers

Fishing communities are facing a sharp decline in catches and have undertaken significant changes in livelihood systems and practices. Different strategies and responses to resource fluctuation at individuals, households and communities level are observed. Transformations to alternative livelihood options and fishing practices (e.g. income diversification towards farming and off-farm activities or (over)capitalization of fishing activities, alternative fishing technologies) are commonly carried out in many small scale fishing communities, prompted by diverse socio-economic background and the external institutional environment (Robards & Greenberg, 2007; Smith et al., 2005). Therefore, fishing communities in Singkarak Lake may have differences each other in terms of their livelihood strategies, though they are having similarities in fishing activities and located in one area with homogenous social and cultural background. Like in other fisheries, management in Singkarak Lake is still focusing in biological and global economic parameter. Meanwhile socio-economic aspect does not get many attention from the managers. Many researches about the fisheries and ecological of the lake have been conducted but very few of them link the ecological issues with social perspective such as the livelihood of resource users within the current condition of lake environment. Lots of management initiatives on fisheries fail because they often overlooked on socio-economic needs and fishers' concerns (Bene, Mindjimba, et al., 2003). Likewise, there are still limited numbers of scientific literature available and there is lack of reliable data on small-scale fisheries (Bene et al., 2009). This chapter assesses the current fishery-based livelihood systems of the fishers. Technical and socio-economic characteristics of households in Singkarak Lake are documented through descriptive statistics, multivariate analysis (Principal Component Analysis, PCA), and clustering (Cluster Analysis, CA), with the objective of developing a typology of fishing households. Then livelihood systems for identified types of households were analyzed.

6.1 Variables and data analysis

A range of variables and their values were calculated from the data. Thirteen variables were selected for PCA, to identify those that most contribute to the heterogeneity of the 200 sampled fishing households in Singkarak Lake. Since households commonly combine diverse livelihoods, with fisheries as pivotal one, variables used in PCA and CA are not solely related to fishing activities but also to farming and off-farm activities. Boat and gear assets are the value of fishing boats and fishing gears owned by the fishers, respectively. Thus the total value of fishing assets is measured as the summation of the value of fishing boats and gears. Annual fishing incomes represents total fishing income earned by the households. Annual agriculture income is the value of goods produced from farming activities. Although productions and catches are also self-consumed, they have not been factored in income calculation. Regarding fish, self-consumption is actually a very small proportion of catches, since households rely on catches to generate cash through sales. Annual operational costs represents total fixed and variable costs of fishing activities. Household's size is the number of households member (the concept of households used in this study refer definition by FAO (1998) namely all persons who live in the same house, sharing incomes, expenses and daily subsistence tasks). Fishing and farming experience are number of years of households' head do fishing or farming which represent human capital. Age refer to the age of household's head. Migrated households' member represents number of households' member who temporarily or permanently stay and work outside the village (mostly in other city or province). Land assets refer to the number of land which is owned, or having access right or cultivated by the households.

The set of variables retained from PCA form the basis of fishermen's households' typology developed by hierarchical cluster analysis, using Ward's method and Euclidean distance as used by Joffre and Bosma (2009) and Tzanatos et al. (2005). Cluster analysis is a classification tool which enables differentiation in population when differences are not obvious (Atlas & Overall, 1994), which is the case here, since all households are fishing to different extent. The analysis determines the optimum number of clusters. The distance between clusters is measured based on variance analysis. Then, from the original value of indicators' means, one-way ANOVA and a Games and Howell post-hoc test are employed to identify which variables are significantly different between the groups. Preliminary KMO and Bartlett tests were performed to check whether PCA were appropriate for the data set and the selected variables could be factored. Measures of sampling adequacy for each variable were analyzed by using anti-image correlation matrix, taking 0.5 as the minimum value. KMO is greater than 0.6, and the Bartlett's sphericity test is highly significant. Therefore, suitability tests support the use of PCA to perform data reduction.

6.2 Fishing households' typology in Singkarak Lake

PCA component matrix was performed on thirteen selected variables with varimax rotation. Using Kaiser Criterion and Eigen value greater than 1, PCA identified four orthogonal linear combinations of these original variables as inputs, explaining 64.1% of total cumulative variance. Pair correlations between variables are shown in a correlation matrix (attached). Expectedly, "total fishing asset value" positively correlate with "number of boat (biduk)", "gear", "operational costs" and "income from fishing". Also, "income from agriculture" shows relationship with land and farming experience, "experience in farming" further relate to "age" and "fishing experience". Moreover, "age" also correlates with "fishing experience" and "number of migrated household members" which then associated with "household's size" and "food expenditure". Factor analysis is validated since many correlation coefficient (r^2) are greater than 0.3 (Tabachnick & Fidell, 2001).

Taking into account component loading with an absolute value above 0.5, component 1 has five main variables with positive signs (Table 6.1). This component represents the fishing effort, combining total value of fishing assets, boat assets (*biduk*), annual fishing income, gear assets and annual operational costs. This component accounts for 18.60 % of the variance. Component 2 relates to farming; it combines three main variables with significant loading: total land owned, annual agriculture income and farming experience. This component accounts for 17.79 % of the original variance. Components 3 and 4 refer to household demography, socio-economic and experience. Component 3 has three significant loadings: age, fishing experience and migrated household members. It accounts for 14.41 % of the original variance. Component 4 has two significant loadings: daily food expenditure and household size. It accounts for 12.30 % of the original variance.

Table 6.1: Rotated Component Matrix from PCA of 13 Variables: Main Components, Correlations and Variances Explained as per Variable

Variables	Component 1	2	3	4
Total value of fishing assets (IDR)	**0.836**	0.139	-0.022	0.103
Boat assets (number of boat/biduk)	**0.747**	-0.082	0.023	-0.039
Annual fishing income (IDR)	**0.702**	-0.032	-0.037	0.077
Gear assets (number of gear)	**0.674**	0.073	0.192	-0.233
Annual operational costs	**0.557**	0.011	-0.247	0.135
Total land owned (m^2)	0.154	**0.891**	0.022	0.013
Annual agriculture income (IDR)	-0.065	**0.887**	-0.016	0.091
Farming experience (years)	-0.027	**0.794**	0.332	0.082
Age (years)	-0.025	0.154	**0.848**	-0.022
Fishing experience (years)	-0.053	0.130	**0.771**	-0.031
Migrated households' member (number of person)	0.022	-0.048	**0.562**	0.263
Daily food expenditure (IDR)	0.024	0.014	-0.017	**0.860**
Households' size (number of person)	0.042	0.161	0.179	**0.827**
% of variance	21.44	19.48	11.68	11.51

The variables are sorted in descending order based on the percentage of the variance explained in PCA (Table 6.1). This highlights the 13 most influential factors for explaining the diversity in the fishing community. Hierarchical cluster analysis based on these 13 indicators indicated the presence of 3 clusters. Then, non-hierarchical K-means cluster analysis was applied and identified the three clusters, as household types. The three household types identified among the fishing community around Singkarak Lake differ in terms of livelihood strategies and socio-economic factors. Table 6.2 comparatively presents the main features of each type. Factors related to fishing activities, agricultural activities, and socio-economic characteristics are significantly different except for the number of migrated household members.

Although income data within each type is variable and skewed (high standard deviation and large differences of mean value), it indicates that fishing income is much higher than other incomes including farming. Except for type II which has slightly higher farming incomes. Capital assets and income diversification differentiate livelihood of each types. Where fishers with more land and fishing assets are better-off than fishers with non-farm activities and have less fishing assets.

Table 6.2: Comparative Quantitative features of each household types identified by K- means cluster analysis

Variables	Household type			P value
	I	II	III	
Household's number	59 (29.5)	60 (30)	81 (40.5)	
Total value of fishing assets (IDR) (x1,000)	16,600 ± 9,121[b]	4,980 ± 3,727[a]	5,790 ± 4,385[a]	0.000
Boat assets (number of boat)	1.08 ± 0.34[c]	0.58 ± 0.50[a]	0.84 ± 0.43[b]	0.000
Annual fishing income (IDR) (x1,000)	14,500 ± 7,873[c]	5,340 ± 3,424[a]	7,350 ± 3,926[b]	0.000
Gear assets (number of gear)	2.73 ± 1.20[b]	1.43 ± 0.75[a]	1,62 ± 0.86[a]	0.000
Annual operational costs (IDR)	154 ± 104[b]	68 ± 42[a]	73 ± 45[a]	0.000
Total land owned (m^2) (x1,000)	14 ± 34.6[b]	6.4 ± 4.5[b]	1.1 ± 3.2[a]	0.000
Annual agriculture income (IDR) (x1,000)	3,590 ± 4,108[b]	6,490 ± 5,243[c]	554 ± 1,719[a]	0.000
Farming experience (years)	16.5 ± 13.8[b]	25.1 ± 12.6[c]	2.3 ± 5.9[a]	0.000
Age (years)	47.2 ± 10.2[b]	51.2 ± 9.5[b]	43.2 ± 9.7[a]	0.000
Fishing experience (years)	25.5 ± 10.7[a]	30.1 ± 10.9[b]	22.4 ± 9.8[a]	0.000
Migrated households' member (number of person)	0.8 ± 1.2[a]	0.9 ± 1.1[a]	0.6 ± 1.2[a]	0.119
Daily food expenditure (IDR) (x1,000)	35.5 ± 13,7[b]	34.2± 10.4[ab]	30.3 ± 10.1[a]	0.024
Households' size (number of person)	6.1 ± 2.5[b]	6.0 ± 1.9[b]	4.8 ± 2.5[a]	0.000

Income, costs and assets in Indonesian rupiah (IDR), during period of study 1 USD = 9,450 IDR
a, b, c: values of variables for each clusters in one row with no superscript in common are significantly different at $p < 0.05$ (from Games Howell Post Hoc Test)

The first type (type I) includes households with highest total income, mostly from intensive fishing. Even though type I shows highest access to farm land, farming earns them half less income than in type II. Type I households have the highest total value of fishing assets and annual fishing income. Type I forms about 30% of the community. Table 4 shows that more than 80% of type I households are crop-farming, and about 37% have livestock. Type I may be named "farming fishers" households.

A second type (type II) includes poorer households with a balanced income from both fishing and farming in almost equal contributions. Type II accounts for 30% of all fishing households. Although type II households have less land assets than type I, they achieve the highest mean agriculture income. Household heads have also the longest experiences in both fishing and farming. Almost all type II households are crop-farming (97%), and about 38% have livestock. Type II may be named “fishing farmers” households.

The third type (type III) includes the households which mostly focus on fishing and off-farm activities for livelihood. Type III forms 40% of the fishing community; about 70% of them are not crop-farming at all (as shown in table 4), mostly due to lack of land. 38% of type III households do only fishing with or without further processing and commercialization, and more than 20% of them have exclusively fishing for livelihood. Overall, type III households have less land assets and income from agriculture than other types. Type III includes fishing households with younger heads, smaller families, little experience in farming (if any). Type III has the highest individual (per household’s member) food expenditures although it has smaller household size. They are specialized in fishing although fishing assets are less than in type I. In type III, livestock rearing involves 30% of all households, and goes along with fishing as a dual livelihood strategy, while it is markedly associated with crop farming in types I and II. Type III may be named “mainly fishing” households.

Some additional figures may be calculated from table 6.2. The household’s return on fishing assets (the ratio between the annual fishing income and the total value of fishing assets) differs between the household types. On average, it is 0.873, 1.07, and 1.26 for types I, II and III, respectively. Poorer fishers (type III) are making more out of their equipment than better-off fishers (type I). Additionally, the return on fishing operational costs (the ratio between annual fishing income and annual fishing operational costs) shows a similar trend; these ratios are 94.2, 78.2 and 100.3 for types I, II and III, respectively. The efficiency and more intensive use of inputs again correlate with the poorest households. The more extensive strategy developed by better-off households (type I) is also indicated by the return on land owned. The ratio between the annual farming income and m^2 of land owned is 255 IDR per m^2, 1016, and 504 for types I, II and III, respectively. Type I households own significantly more land than the other two groups, but they basically do not use it, or not efficiently.

Livelihood diversification is commonly practiced among small-scale fishers particularly in Asia and Africa. They are also engaged in other income generating activities hence they are not considered as full-time fishers (Bene & Friend, 2011). In the case of Singkarak lake, As table 6.2 depicts, there are marked differences between the types in terms of technical and socio-economic features. Group discussions and interviews also revealed that livelihood portfolios have diversified in recent years, including off-farm, non-fishing, informal activities, such as motorbike renting, local transport services, small vending businesses, and tourism-targeted handcrafting. However, other livelihood options could not replace the role of fishing (including fish processing and trading) for households income where fishing is still the biggest part of households revenue for most of small-scale fishing communities (Bene & Obirih-Opareh, 2009; Sarch & Allison, 2001). For Singkarak fishers, fishing is still the main income source which represent more than half of their cash income. The fishers argued that they can get daily cash from fishing while income from crops and farming have to wait until certain period of time. This is in line with Morand et al (2005) regarding factors which increase number of professional fishers, namely the increased need for cash and fishing can satisfy this need by providing daily cash income. Type III households are particularly involved in such livelihoods. Additionally, in most fishing households, fish processing (cleaning and ice-packaging prior to transport to selling places) is common, and it involves many members of each household.

6.3 Livelihood Systems for Different Types of Households

Table 6.3 shows the combination of income sources that are mobilized by fishers in Singkarak Lake. Overall, only 12% of household make fishing as single source of income. About 50% combine primary, natural resource-based activities (fishing with crop-farming and/or livestock rearing). Fishing and crop-farming remains the most common combination of income source (23%). Combination of fishing, crop-farming and livestock-rearing is another popular livelihood strategy (20%). Other households represent highly diversified livelihood strategies, combining fishing, fish processing and commercialization, crop-farming and livestock rearing, and a number of smaller, mostly temporary and opportunistic, non-farming activities. Motorcycle renting, construction works, small businesses (shops and local commerce) are conducted on temporary basis by most of the fishers.

Table 6.3: Livelihood Portfolios per Households Type at Singkarak Lake (Percent of Households per Type)

Livelihoods portfolio	Fishing Households' type			Total (%)	N
	Farming fishers	Fishing farmers	Mainly fishing		
Fishing	5(8.5)	1(1.7)	**18(22.2)**	12	24
Fishing and crop farming	**17(28.8)**	**19(31.7)**	9(11.1)	22.5	45
Fishing and livestock rearing	2(3.4)	0(0.0)	**12(14.8)**	7	14
Fishing, fish processing and sale	4(6.8)	0(0.0)	**13(16.0)**	8.5	17
Fishing, motorcycle renting, construction works, private enterprise, small shop	0(0.0)	1(1.7)	7(8.6)	4	8
Fishing, crop farming, fish processing & sale	3(5.1)	4(6.7)	2(2.5)	4.5	9
Fishing, crop farming and livestock rearing	**16(27.1)**	**17(28.3)**	6(7.4)	19.5	39
Fishing, crop farming, motorcycle renting, construction works, private enterprise, small shop	6(10.2)	6(10)	5(6.2)	8.5	17
Fishing, crop farming, fish processing and sale, motorcycle renting	2(3.4)	6(10)	3(3.7)	5.5	11
Fishing, crop farming, livestock rearing, motorcycle renting, small shop, construction works, local commerce	4(6.8)	6(10)	0(0.0)	5	10
Fishing, livestock rearing, fish processing and sale, motorcycle renting	0(0.0)	0(0.0)	6(7.4)	3	6
Total (percent)	100	100	100	100	-
N	59	60	81	-	200

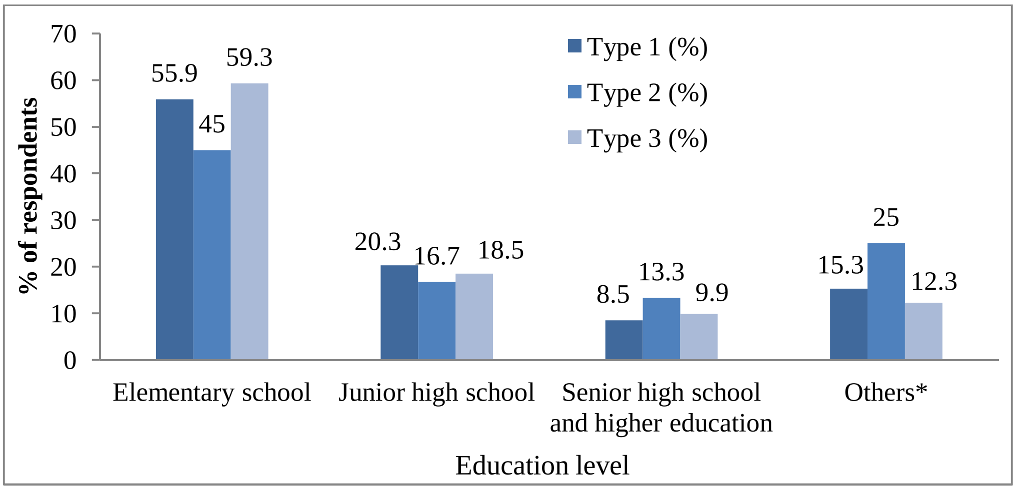
Households commonly combine diverse livelihoods, with fisheries as pivotal one. Differences in household portfolio are marked between types, yet with interesting similarities. Households in types I and II show the same main livelihood patterns as they mostly combine fishing and farming (29% and 32% respectively) and fishing, farming and livestock rearing (27% and 28% respectively). As said, the main difference lies in the higher fishing effort in type I (higher fishing costs and asset, leading to higher catches and income), while type II is poorer overall, and has more farming activities. Type III shows a completely different livelihood strategy, more fishing-oriented and yet with diversified off-farm activities.

This preliminary socio-economic and technical analysis reveals contrasted livelihood patterns and performances (income as per activity), and, more particularly, marked differences in fishing effort (costs and assets) and outcome (income). While all sampled households are fishing, fisheries actually have different statuses among households. Farming fishers' households (type I) focus on fishing with high inputs, resulting in higher fishing income. Type II is rather a farming type, where fishing complements farming, with lower level of input and lesser performance. For these two types, combining fishing and farming is made possible through access to land and forms the pivot of their livelihoods. The function of land (*pusako* land) for Minangkabau people is not only to provide economic resources for lineage members but also for social security and continuity of their lineages (von Benda-Beckmann & von Benda-Beckmann, 2004). Although fishers have more fishing assets, having access to land or owned land is considered as social status and security.

Type III relies mostly on fishing as livelihood, yet with low level of inputs; fishing is combined with several temporary, off-farm options. From sustainability perspective, in view of declining fish resources, types I and III seem more vulnerable than type II. Assuming sample representatives, type III households form 40% of all fishing households at Singkarak; about 40% of them do only fishing with or without further processing and commercialization of catches. Such households are clearly most exposed to declining lake resources. Although quite specialized in fishing, type I households have access to farming land and can potentially turn to more intensive farming as an adaptive strategy to lake-related issues. Type II already shows such dual farming-fishing strategy. Type III has fewer options for livelihood diversification and typically turns to livestock when land access allows, and to temporary, opportunistic off-farm options. As shown by Ellis (2000), better-off households are able to diversify into more favourable labor market options than poor households. This is due to limited access to land and land ownership of poorest households. As a consequence, they tend to choose off-farm activities which require less investment and capital such as construction works, paid labor and small businesses.

Since fisheries resources are decreasing in Singkarak, fishing households also engage in various non-farming livelihoods strategies involving activities such as construction works, small businesses, small shop, motorcycle renting and livestock rearing. Interviews with head of *Nagari* and fishers revealed that most non-farming activities are seasonal except for livestock rearing, usually run by family members. The global diversification trend observed in rural areas of developing countries (Ellis, 1998) is also happening in Singkarak Lake.

Migrating to other fishing area (to other Nagari) to get better fish catch is not commonly practiced. The fishermen keep doing their activities as usual and at the same place where they used to do fishing because they are not allowed to fish in other areas which has better fish catches if they have not become part of the Nagari through marriage. Although this is viewed as socially constructed constrain evolved through practices and beliefs. As the consequence of their immobility, fishers continue fishing despite the decreasing trend of fish catch and earning less than the past (Panayotou, 1982).



*others = illiterate, ever been in school but not graduated

Figure 6.1: Education Level

The immobility of fishers in Singkarak lake is also because of many other reasons such as low formal education, advanced age and preference for fishing as way of life and 'savior' of their family life to secure the foods and stipends for the day or at least the foods (Panayotou, 1982). Although education level of fishers did not seem to be significantly different among fishers' group (chi-square = 5.9, df = 6, $p>0.05$), findings suggest that in overall, more than 50% of the fishers had elementary level of education (Yuerlita & Perret, 2010). There is very weak evidence of relationship between education level and type of fishing households (chi-square = 5.9, df = 6, $p>0.05$). Therefore, fishers with poor endowments such as land and livestock force them to work in other farm as paid labour or other off-farm activities. While farming fishers and fishing farmers (having land or livestock) diversify into farming and livestock rearing.

Most of the fishermen (70.5%) committed that they will not stop fishing which shows that fishing is one of the main livelihood activities. Moreover, diversification is one most important survival strategy although many fishers get support from their family members who migrate to other cities for working but working in other cities and earning can be a better choice only for the younger generations. Family members (mostly 20 – 30 years old) temporarily stay and work in other city, particularly java island. Out migration has been part of Minangkabau society. Sending family members to work in other areas or cities is also perceived as one of the coping strategies to the decreasing fish catch. Result showed that an average of 5.7 years has been spent living in cities for earning cash since 2003. The more migration of the people to the city is found to coincide with the decline of bilih fish production at the same time. Based on the data from fishers association surrounding Singkarak Lake, their income has decreased for about 10,273 USD (2003).

Migration is becoming an important and priority option within household which is also triggered by lack of livelihood assets such as natural capital (landless), financial capital (limited access to credit scheme) and the success of other household which has had better life because of remittances from the migrated family members. Family members, who migrated, adapted to more quickly with new living condition, getting job through networking than who did not. About 38% of the fishing households send their family members working in the city. The total number of family members migrated however do not show significant difference between the three types of fishing households. About 31% of migrated household member belongs to fishers in type one, while 36% and 33% are migrated households members from fishers' family in type two and three, respectively. Characteristics of migrated family members is given in table 6.4. Fishers in type I has the lowest number of migrated household members although this type has biggest households' size. More than half of the migrants are male and most of them work as merchant or retailers. They cannot compete to get better job because low education and lack of skills. Female migrants mostly work as the shop keeper, housemaid and retailers. Fishing household usually send their son or daughter to migrate to cities because of facing difficult condition with the current living condition particularly due to declining fish catch, less income and less labor needed for fishing.

Table 6.4: Characteristics of Migrated Family Members

Characteristics	Frequency (percentage)
No of households whose member migrate (n = 200)	76 (38%)
No of people migrate	146
Sex (n = 146)	
Male	86 (58.90)
Female	60 (41.10)
Age (n = 146)	
< 20	24 (16.44)
20 – 30	88 (60.27)
31 – 40	24 (16.44)
41 – 50	10 (6.85)
Education (n = 146)	
Illiterate	1 (0.68)
Elementary school	23 (15.75)
Junior high school	44 (30.14)
Senior high school	68 (46.58)
Diploma	5 (3.42)
Bachelor degree	2 (1.37)
Other	3 (2.05)
Average years been left	5.7

The livelihood patterns observed in Singkarak concur with those described in recent literature. Livelihood diversification is a common trend in fishing communities, particularly in developing countries (Allison & Ellis, 2001), either as a coping (short-term) strategy, or as an adapting strategy (long-term). It involves activities such as farming (Neiland et al., 2000; Sarch, 1996), both farming and livestock herding (Geheb & Binns, 1997) or out-migration (Njock & Westlund, 2010; Sarch & Allison, 2000). For instance, fishing communities in West Java commonly switch between rice farming, fishing or seasonal migration as a response to the variability of catch (Allison & Mvula, 2002). In the case of Singkarak Lake, farming is considered an established long-term strategy by type II households, and more as a possible future option by type I household; both types show experience in both fishing and farming already anyway.

Although fish resource depletion and fluctuation would certainly affect the income of the fishers, vulnerability analysis by Mills et al. (2011) reveals some other source of vulnerability of small-scale fishers including lack of access to land and farming equipments, food insecurity, health issues and lack of access to credit facilities. The latter three causes of vulnerability were also experienced by non-fishers community. In Singkarak Lake, fish resource depletion and fluctuation of fish production do exist which is caused by several factors, therefore diversification is seen to be one of the coping strategies to deal with vulnerability. In almost similar situation, small-scale fishers in the Mekong region also confronted with declining profits, there is a need to promote non-fisheries sector such as farming and non-farm activities to maintain livelihood of the fishers (Navy & Bhattarai, 2009). Having access to land and farming equipment, fishers would able to diversify their income with farming activities. Hence, full-time fishers are considered as productive but reveals to high risk and highly vulnerable while fishing farmers are generally more risk-averse but less efficient (Bene, 2009; Smith et al., 2005). Most of fishers in Singkarak Lake are not belongs to full-time fishers. Most of them engage in diverse livelihood options. The three types of fishing households practice differs livelihood portfolio, therefore their efficiency are presented for each households' type.

6.4 Summary

Analysis of socio-economic and technical features of fishing households, revealed the co-existence of three main household types involved in fishing, with significantly different technical and economic features that challenge the usual, homogenous, yet vague image given by official statistics. Type-I households are farming fishers; type-II households are fishing farmers; and type-III households are mainly fishers; poorer diversified fishers. Further, results show that the return on fishing costs, and the return on land owned are markedly different between types. Type II shows the highest land productivity, and type III show the highest return on fishing costs. Type I, while enjoying relatively higher living standards.

The analysis identifies a very vulnerable group (type III; 40% of the whole population). Type III households are mainly fishers, they are not farming but they relying on diverse non-farm, opportunistic, temporary activities. Although not a majority group, it confirms the stereotypical view that fishery, as single option, rhyme with poverty (Bene, 2003). However, off-farm diversification is underway, prompted by insufficient fishing income. Paradoxically, farming-fishers households (type I), showing higher fishing and total income are the least efficient in fishing activities.

The chapter concurs with previous research (Pomeroy, 2012) that suggests a focus on people and community-related solutions, through an integrated, three-fold approach of resource conservation (assessing the relevance of existing regulations on net mesh size, developing new ones), livelihood improvements (supporting type-III households' diversification with training, capacity building, financial support to entrepreneurship and business development) and restructured governance. *Nagaris* should clarify local institutions on the status of aquatic resources, the property rights thereof. They should engage fishing communities towards co-development of common, accepted objectives and adapted measures for resource protection and sustained local fisheries. From a methodological viewpoint, the case study demonstrates that multivariate analysis combining PCA and cluster analysis provides a relevant and synoptic representation of the household diversity regarding livelihoods, socio-economic features and performances. The different type of fishing households obtained from typology yield specific key information to identify problems and opportunities to deal with the problem appropriately based on the needs of each type. For the purpose of this study, fishing strategy of each type is revealed by analyzing their efficiency level and suggest for more efficient fishing practices for each type and strategies employed to deal with declining fish resource.

Chapter 7

Technical efficiency and fishing strategies of Singkarak Lake's Small-scale Fishers

Given the complexity of problems faced by fishing communities in Singkarak Lake such as degraded lake resource, decline of fish catches, hence low income. Fishers response to resource decline in many ways including more intense fishing practices or combining income source with other livelihood activities (diversification). Fishing intensification is commonly practiced particularly in an open access resources such the case of Singkarak Lake. Fishers put more efforts in fishing includes using more gears or even increasing fishing hours. The fishers do not realize that their decision to put more efforts might have adverse impact to their livelihood and resources. Small-scale fishers can make profits therefore they become more resilience to shocks and stresses but on the other hands fishers may have exploited resources and jeopardize the environment (Colin-Castillo, 2011). This condition is getting worse when fishery is weakly regulated and exclusion of efficiency criteria in lake management. Therefore there is a need to link management of small-scale fishery with efficiency criteria which is now still inadequately implemented. Management authorities are typically put more attention on biological aspect of fisheries than socio-economic performance of the fishers. From policy point of view, answer to the question whether fishers have operated at efficient level of resource use or is there any potential for improving performance of fishing practice? might contribute in designing policy instrument to address the issue of poverty while maintaining the sustainability of the resources. This chapter aims to estimate frontier production function and individual measures technical efficiency the fishers in Singkarak Lake. These measures are then grouped based on the characteristics of fishers type. The slots for improving fishing performance of the fishers were discussed based on the characteristics of fishing households' type and derives recommendation for efficient policies targeting fishing and livelihood issues in this area.

7.1 Approach to efficiency measurement

Non-parametric approach, data envelopment analysis (DEA) is applied in measuring technical efficiency of fishers in Singkarak Lake. DEA is non-parametric production frontier approach measuring efficiency of individual decision making units (DMUs) in a particular group which was originally developed by (Charnes et al., 1978) based on the work of (Farrell, 1957) on frontier models. DEA has been suggested by FAO (2000) as a useful program to estimate technical efficiency, capacity and capacity utilization (CU). It is a preferred method in most literatures due to its ability to incorporate multiple inputs and outputs in the analysis, it does not require any particular functional form of the production frontier on the data (Fare et al., 2001; Pascoe, 2007). The shortcoming of this approach is that it does not provide relationship between individual input and output or between the outputs and it also sensitive to random error due to it's a non-parametric approach. However, the effect of random variation can be solved by using the average of the data over some years with the consequence of the information lost on the changes of capacity utilization (Ruggiero, 2000).

Production frontier in fisheries are defined as the function of fishing efforts and stocks abundance (Cunningham & Whitmarsh, 1980). In fisheries, the technique has been widely used to the Spanish coastal trawl fishery (Vázquez-Rowe et al., 2010), measuring technical efficiency of English Channel fisheries (Tingley et al., 2005), FAO fisheries technical paper in measuring fishing capacity (Pascoe et al., 2003), capacity and economic efficiency of small-scale fisheries in Mediterranean Sea (Madau et al., 2009; Maravelias & Tsitsika, 2008), capacity of Malaysian purse seine fishery (Kirkley et al., 2003).

Technical efficiency (TE) may be defined as either the optimum combination of inputs to produce a given level of output (input oriented) or the optimum outputs produced from a given combination of inputs (output oriented). The comparison between actual output values and production frontier represent the efficiency (Kumbhakar & Lovell, 2000). In view of situation in Singkarak Lake (i.e., poverty and declining resources), this study is aim to determine the method of input oriented by which efficient household can minimize fishing effort (the use of fishing inputs) while achieving optimal output (catches and income). To that aim, input oriented approach under variable-return-to-scale (VRS) model is used. Technical efficiency score was derived from a frontier function of variables as constrained inputs. Scale efficiency (SE) is calculated based on ratio of CRS and VRS scores.

7.2 Data for Efficiency Analysis

In the case of fisheries, technical inefficiency is relevant to determine in which extent fishing inputs can be reduced to achieve high level of efficiency in fishing practices. Technical efficiency and scale efficiency of fishing practice is determined using all fishing households as decision making units (DMUs) as the reference group. Then, the technical efficiency, scale efficiency is analyzed based on the three types of fishing households. Data are from the households survey using four inputs variable and single output. Table 7.1 present descriptive statistics of the selected input and output variables of households participated in fishing. The four input variables are number of gear, number of boat, operational costs and number of fishing days in a year. While the output variable is amount of bilih catch per year.

Table 0.1: Description of Variables Used in DEA Analysis

Variable	Description	mean	std.dev	min	Max
Inputs					
Gear	Number of fishing gear	1.89	1.09	1	6
Boat (biduk)	Number of boat (biduk)	0.84	0.47	0	2
Costs	Operational costs (IDR)/year	95465.3	77298.2	0	560000
Fishing days	Average fishing days/year	328.4	62.5	52	364
Output					
Bilih catch	Production of bilih/year (kg)	12610	801.4	140.8	14520.1

There is a huge gap between the average annual fishing yield (bilih production) and the minimum fishing yield. This implies that there is possibility of the fishers to improve average fish catches given the available resources or reducing the excessive inputs which might indicate overcapitalization.

7.3 Fishing Efficiency Analysis

The results of technical efficiency with VRS, CRS and NIRS model for overall households and by households type are given in table 7.2. It shows the overall inefficiency of fishing activities in this area. Like in many other efficiency studies of small-scale fishing communities, on average the fishers were not technically efficient and there is a room for efficiency improvement (Aisyah et al., 2011; Esmaeili & Omrani, 2007; Sesabo & Tol, 2007). Under the VRS model, the mean value of technical efficiency (TE) for individual sampled fishers is about 74% and standard deviation 28. This indicates that, overall, the fishers could produce the same level of output if they were operating by using 26% less inputs. Efficiency measures of all fishers is classified based on the households type from typology analysis. Type I fishers has the lowest efficiency compare to type II and III.

Table 0.2: Technical Efficiency and Scale Efficiency of Fishing Households in Singkarak Lake

Input	All fishers		Fishers type I		Fishers type II		Fishers type III	
oriented	Mean	SD	Mean	SD	Mean	SD	Mean	SD
TE_{VRS}	74.07	27.76	54.01	20.92	88.00	22.85	78.36	27.46
TE_{CRS}	33.52	25.07	31.86	23.76	38.34	28.65	31.17	22.89
SE	44.78	24.98	55.31	23.47	42.30	27.64	38.95	21.51
TE_{NIRS}	33.52	25.07	33.52	25.07	31.86	23.76	31.17	22.89
RTS	IRS		IRS		IRS		IRS	

The difference between TE_{VRS} and TE_{CRS} indicates that the production unit has scale inefficiency (Fare et al., 2001). Scale efficiency determine whether a producing unit operate at the optimal scale of operation or what should be the optimal scale of operation. The comparison of TE_{CRS} and TE_{VRS} gives the scale efficiency score. Average scale efficiency for each type of fishing households are 55.31% (type I), 42.30% (type II) and 38.95 (type III) suggest that reaching an optimal scale, every production unit would reduce technical inefficiency 44.69%; 57.70%; and 61.05% respectively for households type I, II and III

Results show individual TE for each fishing households. TE may be regrouped as per household type or for the total population. It must be highlighted here that any TE is only a relative metric for efficiency, which depends on position of other households along the efficiency curve. In other words, households that are defined as 100% efficient optimize input use towards a maximum output only in comparison with all other households. Input-oriented efficiency analysis also provides the percentage of a given input amount that could be spared in order to achieve full technical efficiency (input-reduction percentage). Specific inputs (with high input-reduction percentage) may be spotted as highly inefficient. This serves as an important indicator of the strategy pursued, overcapitalization (excessive fishing effort, maximum use of resources but productivity may decreases) or intensification (less factors used for same output, productivity increases).

Efficiency measurement from different model specifications (VRS, CRS and NIRS) provides practical information to identify the extent of returns to scale of the samples whether it is increasing returns to scale or decreasing returns to scale. As shown in table 7.2, individual efficiency measurement of the samples indicates increasing return to scale inefficiency. The same results shown by average results for all model specification by households type where the inefficiency is caused by increasing returns to scale. Thus, all inefficient fishers could have catch more fish given their current input mix which means the fishers should reduce their current inputs to operate efficiently with the same level of output.

Distribution of efficiency among the all sampled fishers is presented in Table 7.3 which is grouped into four range of efficiency. Overall about half (51%) of the fishers operate at full (yet sample-defined) technically efficiency. Full technical efficiency implies that those group of fishers is the most efficient in producing a given output level by the given inputs. Most of the individual fishers operate in the range of 50 – 99.99% of inefficiency level and about 22% of the individual fishers are operate in the lowest efficiency range (20 – 34.99%).

Table 0.3: Classification of Fishing Technical Efficiency with Potential for Input Reduction

Efficiency (%)	Frequency (%)	Average input reduction (%)			
		Gear	Boat(biduk)	Operation cost	Fishing days
20 – 34.99	22 (11)	-68.77	-71.77	-77.42	-68.44
35 – 49.99	17 (8.5)	-63.37	-67.26	-65.45	-57.44
50 – 99.99	59 (29.5)	-47.53	-52.40	-66.09	-45.83
100	102 (51)	0	-	-	0

Table 7.3 also provides a classification of TE with respective frequency and potential for input reduction to meet full TE. Overall, the four studied inputs show high input-reduction potential, up to 70 – 80% for the least efficient households. More specifically, number of boat (biduk) operated and amount of operation costs require most optimization efforts. Potential gear input reduction for the least efficient group (efficiency ranging from 20 to 49.99) should also be consider in the optimization efforts.

Technical efficiency as per fishing household types is presented in table 7.4. Paradoxically, type I is the least efficient type overall (average TE: 54%), although with higher income from fishing. Specifically, three inputs could be more sparingly used and optimized, namely numbers of fishing gears, boats (*biduk*), and fishing days (around 50% reduction potential each). This shows a typical case of overcapitalization, made possible by the relative wealth of the group. Conversely, fishing farmers in type II are the most efficient with 88% TE on average. About 75% of the fishers in this type operate at full technical efficiency (100%). Type III diversified fishing households are also quite efficient with an average TE of 78%. Both type II and III show high efficiency in all inputs, with the marked exception of fishing operation costs (66% and 76% of reduction potential respectively). Yet again paradoxically, the poorest fishing households are wasting resources in operation costs, with large room for optimization.

Table 0.4: Technical Efficiency by Households Type and Target Quantities for Input Reduction

Household type	Average efficiency (%)	Average input reduction (%)			
		Gear	Boat	Operational costs	Fishing days
Type I	54.01	-48.43	-52.19	-66.62	-46.61
Type II	88.00	-13.73	-23.49	-65.78	-16.74
Type III	78.36	-21.76	-33.53	-76.08	-25.80

Type II households show the lowest fishing performances (lowest fish catch, hence lowest income) and yet are the most efficient in optimizing input resources, compared with types I and III. Type I households show the highest fishing performances but operate at the lowest technical efficiency level, far below the average TE of all fishing households (74%). Type I shows sub-optimal use of all production factors with same output thus productivity may decrease (overcapitalization). This group is better-off than others but having the lowest efficiency. Type II and III only show marked sub-optimal use of fishing operation costs (intensification). In view of declining fishing resources, type II demonstrate a most interesting livelihood strategy and operation mode, as it balances farming and fishing livelihoods, with high efficiency in fishing operation, high total income, and a number of off-farm, non-farm diversified activities.

Comparing average efficiency level and input reduction of the fishers, there exist heterogeneity. Indeed, Sesabo (2007) report the same findings and reveal that households characteristic play important role in determining efficiency level. For example, households with more income from non-farm activities are found to be more efficient than others because landless fishers have low valued of fishing capital comparing to better-off fishers (in this case, fishers who have access to land). This views in line with the findings from the current study that the more efficient households from type II and III are having very less land compare to type I. Fishers who have land assets tend to have high fishing capital thus they opt to increase their efforts to keep up with declining catches. Meanwhile, landless fishers have more income from non-farm activities and low value of fishing capital. Therefore, this type of households response to the decline by allocating most of their labor into other employment activities while keep fishing with less or same input factors.

Although open-access resources might not be the only cause of fish depletion in Singkarak lake, the fact that it is an open-access fisheries where fishers easily do fishing with unlimited times and gears. Thus, the efficiency of the fishers is an important issue to consider. Excessive efforts and opportunities incomes indeed have exacerbated the fishers livelihood and resource sustainability; the fishers remain poor and resources are jeopardized. This phenomena has been studied which link the declining resources, poverty and open-access resources.

> “that the plight of fishermen and the inefficiency of fisheries production stems from the common property nature of the resources of the sea is further corroborated by the fact that similar patterns of exploitation and similar problems in other cases of open access” (Gordon, 1954).

> “all of these effects – stock depletion, poor economic and instability – result from treating the resource (the fish) as common property until they are caught...” (Pearse, 1992).

> “...this open-access equilibrium dissipates the wealth (or rent)... The result has been that excessive effort is used in fishery, fish stocks may be dramatically reduced and fishermen tend to remain poor with incomes little more than their opportunities incomes” (Heaps & Helliwell, 1985).

Addressing fisheries depletion, particularly endemic species in Singkarak lake is now become an urgent issues. From previous studies policy makers have been informed about the biological aspect of fisheries depletion. Moreover, the current study provide other perspectives in designing and implementing policy instruments which should be linked with the existing livelihood diversity and efficiency criteria. Those two aspects are complementary each other and highly related in the sense that improving efficiency by utilizing the existing resources and skills of the each fishers’ type.

7.4 Summary

Substantial heterogeneity of fishing technical efficiency was found among the fishers. They are diverse not only in their livelihoods type but also diverse efficiency of their fishing practices. The efficiency results suggest that the fishers could produce the same amount of output by reducing the current inputs use. Thus, they can operate at higher efficiency level. A more detailed analysis of the technical efficiency of small-scale fishers was performed. The overall technical efficiency remains low. Farming-fishers households (type I), which have higher fishing and total income, demonstrate the least efficient fishing activities. This result indicates overcapitalization in fishing; excessive inputs and efforts lead to higher catches “*at all costs*”. This type of strategy contributes to the economic viability at the household level (as long as it can withstand the high production costs), but it potentially places more pressure on fish resources. This scenario illustrates the views on the inescapable trade-offs faced by social-ecological systems in search of sustainability. Fishing-farmers (type II) show the least vulnerable livelihood system and high technical fishing efficiency. The mainly fishers (type III) are very dependent upon fishing (representing 93% of the total on-farm income). Their high efficiency reveals an intensification strategy, which is coupled with off-farm diversification.

Chapter 8

Summary of Findings, Conclusion and Recommendation

8.1 Summary of findings

This research aimed at elucidating how local riparian people in the Singkarak Lake area respond and adapt to a fast-changing situation fraught with environmental degradation, and declining fish resources. The general objective of this study was to better understand, document and model the actual diversity in livelihoods, practices and performances of SSIF along the Singkarak Lake.

The specific objectives were: (1) to describe the inland capture system in terms of characteristics of fisheries, resources, resource users, institutions, and the current management features; (2) to document and represent the diversity of small-scale fishing communities and to identify the main socio-economic and technical indicators that contrast the livelihoods of small-scale fishing households; (3) to reveal fishing strategies.

8.1.1 A multi-faceted diagnosis of the situation

A synoptic overview of the study's findings is shown in figure 8.1. The **DPSIR** framework was used to summarize and link up both the results gained and current knowledge from existing literature.

Several main **drivers** of Singkarak Lake's environmental and socio-economic dynamics are identified. First, the sustained demographic development around the lake leads to increased overall pressure on resources (fish population, land use, pollution and waste disposal). Second, the raising need for energy in Sumatra justified the development of the HEPP hydropower plant. Third, fishing remains a key activity and livelihood feature for most riparian population.

An analysis of the institutional context, as a **response** to the situation, revealed that, on the one hand, traditional institutions (*nagaris*) regarding land use are strong and vivid, while they are vague and ill-adapted to the fast-changing challenges related to water and aquatic resources. On the other hand, current policies and regulations do not measure up to the daunting socioeconomic and environmental challenges. Policy gaps, poor administrative implementation, control and enforcement are unable to channel the drivers and minimize their negative effects.

These drivers generate a number of **pressures**: on fish resources (due to sustained fishing activities), on water resources (due to erosion on riparian land, pollutions and waste disposal, operation of the hydropower plant).

Pressures result in **states and trends** such as overall lake environmental degradation (water quality decrease, lake level fluctuation), and, more specifically, declining fish resources (lower quantity, diversity, quality). A continuous decline of catches over the last 15 years is recorded, featuring a spectacular plunge of 50% in 1997 compared to 1996. The resulting **impacts** that are observed in recent times are regional environmental degradation, declining fishing incomes, and persistent poverty.

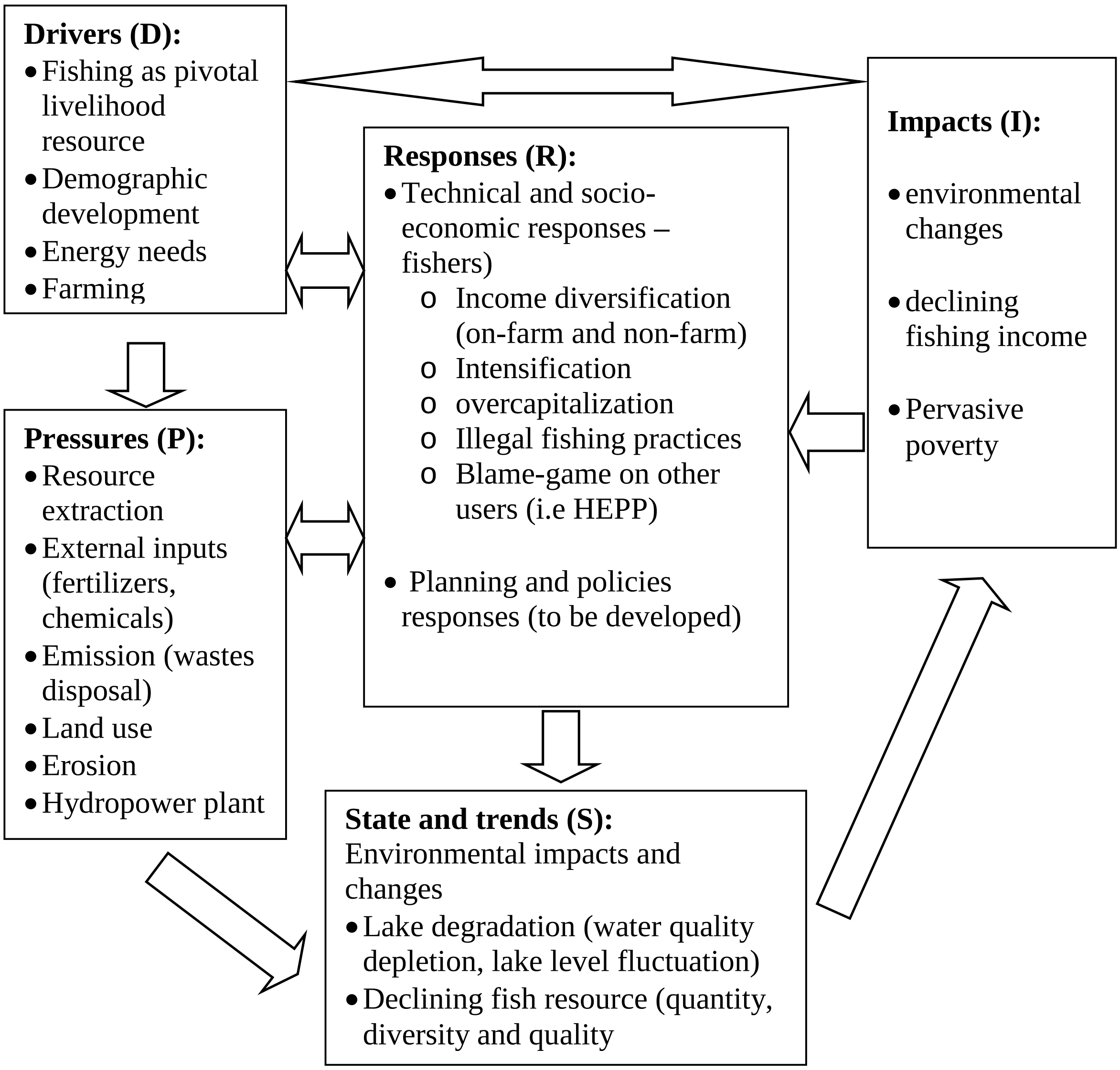


Figure 8.1: A perspective on the Research Findings Using DPSIR Framework

8.1.2 Responses from local people

Faced with these impacts, local people **respond** to the situation in various ways.

First, local fishermen massively blame declining water quality and the hydropower plant for excessive fluctuation (and overall decrease) of lake water level. While water quality analyses and indicators clearly show a declining trend over recent years, changes in lake water level could not be confirmed; it hardly changed after the HEPP was built and operated, and also depends on climatic conditions and intake from tributary river.

Second, some fishermen choose to intensify fishing and increase catches using illegal and environment-harmful techniques such as dynamite blast and poisoning. These remain minority practices, and yet, they are not clearly condemned or ostracized by local institutions or authorities.

Third, and more importantly, the research revealed that, in spite of declining resources and catches, fishing remains a key livelihood and activity among most households, although with some changes. Fishing households tend to diversify their livelihood strategies, and their fishing strategies, while fishing practices remain quite homogenous among households.

Most fishermen use set gillnets and casting nets. The endemic, high-value Bilih fish is the main target and catch. Processing, packaging, transport and trading also often involves household and local workforce. Many fishers sell their catch at the landing sites to local traders who trade in local markets or with other regional traders.

The diversity of livelihood strategies in Singkarak lake has been documented and modelled by analysing the socio-economic and technical features of fishing households, then by developing a typology of fishing households. The approach revealed the co-existence of three main types of fishing household, with significantly different technical and economic features that challenge the usual, homogenous, yet vague image given by official statistics.

Type-I households are **farming-fishers,** who account for 30% of the total sampled fishing households; type-II households are **fishing-farmers** (30%); and type-III households are mainly fishers or **poorer diversified fishers** (40%). Further, results show that fishing incomes, and farming incomes are respectively markedly different between types. Type II shows the highest land productivity, and type III show the highest return on fishing costs. Type I households enjoy relatively higher living standards. Type I and II combine fishing and crop farming or fishing, crop farming and livestock rearing. Type I and II have access to agricultural land, while fishers in type III do not have land. Therefore, livelihood system of households in type III is mostly focusing on fishing or fishing and livestock rearing, or fishing and fish processing, and also off-farm diversification.

Differences in livelihood strategies and resource endowments (especially land) lead to marked discrepancies in performances and income. Key indicators that differentiate fishing households in Singkarak Lake relate to both fishing and crop farming sectors, as already shown in similar research (Neiland et al., 2000; Sarch, 1996). While fishing and related activities remain pivotal in community's livelihoods, farm and off-farm diversification activities are clearly adopted by most households, as an opportunistic choice (type I) or as coping strategies (type III).

To ascertain the performances of fishing practices, and the underlying strategies thereof, an analysis of fishing technical efficiency has been conducted using Data Envelopment Analysis. The results show that overall average technical efficiency is about 75% with standard deviation 28%. This implied that there is still ample room for improving fishing performance of the fishers. With similar catches, fishers could decrease fishing costs by 25%, hence getting higher income. Overall, only half (51%) of the fishers operate at full (yet sample-defined) technically efficiency.

Technical efficiency of each household type was also measured. Type I households (farming fishers), with highest fishing income and total income, are the least efficient households. They tend to overcapitalize on fishing activities, especially with equipment. Fishing-farmers (type II) show high technical fishing efficiency, and arguably the least vulnerable, most balanced livelihood system of all. The poorest fishers (type III) are very dependent upon fishing (representing 93% of the total on-farm income). Their high technical efficiency reveals an intensification strategy, which is coupled with off-farm diversification.

8.2 Conclusion and policy recommendation

A resource that is declining

Overall, fishermen's strategic decision to continue and increase fishing efforts can only further jeopardize the resource, and ultimately their own livelihoods. This is especially crucial for type III households, who depend much on fishing, and have little room for adaptation. Type I households still depend much on fishing but, as better-off landowners and farmers, they have alternative livelihood opportunities. Yet, their extensive, overcapitalized fishing strategy puts pressure on the resource.

While all parties confirm the decline of the fish resource, they have different diagnoses to explain the causes. In particular, experts and scientists point out overfishing and unsustainable (and illegal) fishing practices, while fishers allude to water quality decline and increased competition between uses, including hydropower.

Although the research does not provide its own diagnosis, it notes that existing regulations on net mesh size are not implemented nor enforced. The mere fact that such regulations exist shows that provincial authorities do recognize the issue and the need for more sustainable fishing practices. However, local traditional authorities (*nagaris*) and the fishers themselves have yet to come to terms with the role played by fishing practices in the issue. Institutional analysis shows that *nagaris* have the jurisdiction and the potential power to set up, implement and enforce adapted regulations towards more sustainable fishing practices. **Involving fishermen groups and making them come to terms with own unsustainable practices and their role in fish resource decline is the challenge to be met. This must be done urgently, in view of the sharp decline in fish catches. Existing regulations on net mesh size and illegal practices must apply, and possibly new ones must be discussed and negotiated with all parties (e.g. limitations on number of gears, which would mostly affect type I households). The pollution and environmental degradation which have been resulted from various aspect of interlinked human activities (economic development) should be given a priority thus helping to maintain fish resource habitat. This can be done through many ways such as providing garbage disposal facilities (preventing people from dumping the trash to the lake), cleaning lake shore areas and delineating conservation areas.**

Policies to support small-scale inland fisheries

The research results concur with previous research on small-scale inland fisheries in developing countries. SSIF are marginalized in development planning, threatened by depleted resources and poverty, expose to shocks and stresses, which make them more vulnerable. They are often considered as minority socio-economic features, and broadly homogenous in practices, strategies and outcomes. In fact, many fishing communities demonstrate heterogeneity in terms of socio-cultural and socio-economic characteristics (Neiland et al., 2000). The wide range of livelihood activities performed by the fishers is considered as the response to external risks factor and the changing institutional and policy environment (Smith et al., 2005). Particularly, livelihood diversification is the main feature of small-scale fishers when confronted with depleted fish resources (Allison & Ellis, 2001) and poverty (Islam, 2011; Olale & Henson, 2012). Small-scale fishing communities are commonly found in developing countries, yet this sector is poorly investigated (Battaglia et al., 2010). Moreover, socio-economic and financial analysis are still lacking in helping formulating policy direction.

The results presented in this study shows that small-scale fishers in this area exhibit diverse socio-economic characteristics though they have high homogeneity in fishing practices. Important differentiation criteria are the proportion of income from fishing and the relationship with farming and other non-farm income sources. Detailed socio-economic analysis, such the present typological work, would lead the managers to define more appropriate and applicable development strategies (Cunningham, 1994; Neiland et al., 2000).

Authorities and policy makers must first acknowledge the diversity of small-scale fisheries systems along the Singkarak Lake, develop similar approaches on broader, more participatory basis (involving traditional authorities and fisher groups). Then, they should use the results to design specific targeted actions. Examples are discussed here below.

Determinants of income diversification vary between communities. Olale and Henson (2012) found that level of education, access to credit, and memberships of association are the key factors shape the income diversification patterns among fish workers in Kenya. This study shows that education level is not a good predicting variable, probably because it is not significantly different among the fishers' group. Livelihood diversification patterns in Singkarak lake fishing communities are rather highly influenced by access to land and land ownership. Poorer, landless households tend to choose off-farm activities as it requires less investment. The finding from this study support conclusions from Ellis (2000), who showed that better-off households are able to diversify into more favorable options than poor households.

This research points out that policies and actions to support small-scale inland fisheries and the poorest households shall not be considered in isolation. Results show that fishing and livelihood strategies are drafted based upon factors that are not related to the lake itself, such as land access or opportunities for non-farm income.

This research also confirms that the technical efficiency of small-scale fisheries is highly influenced by households' characteristics (Sesabo & Tol, 2007). Actually, the approach allowed to first identify livelihood strategies, and then to reveal fishing strategies within these livelihood systems, using technical efficiency analysis. In general, there is room for improving fishing performance in Singkarak Lake, through the more efficient use of fishing factors. **Type I households are the main fisher in quantity and income, and are inefficiently overcapitalizing in fishing, while significant income is also generated by farming and land renting. Those households should be encouraged to lower their fishing efforts, with regulations on boat number and size for instance. Promoting aquaculture is an alternative income and employment for type I households because they have capital to invest thus reducing pressures to limited fisheries resource. A shift towards farming may also be promoted, since they own land. The enforcement**

of existing regulations on net mesh size restriction would affect catches by all types but primarily would reduce type-I efforts. The reasons why these households remain in fishing with such highly inefficient practices and ever-declining catches remains to be studied.

What to do with the most vulnerable group?

Specific support should address type III households, with improved access to land for crop farming (possibly from type I, which households are not fully using land), and more sustainable livelihood diversification towards off-farm, non-farm activities. Promotion of land renting between farmers, including local participatory experiments, possible incentives to willing demonstration farmers, capacity building and support on simple land contracting and renting paperwork, may be carried out. Among fishing communities, the poor must be the main target for direct financial assistance such as access to credits or subsidies (Smith, 1979) Yet, in the case of Singkarak Lake, credit or subsidies shall not be used to further invest and extensify fishing activities.

Type III households are the most efficient fishing households, they use their scarce equipment and factors sparingly and wisely, while ever looking for diversified, non-fishing sources of income. So, measures to help them find and develop off-farm livelihoods should be promoted. This involves training and capacity building, financial support to start-up small businesses, access to markets and credit. Engagement in aquaculture could also be an option for supplementary income of type III households through subsidies or financial support from government or local authority.

In planning for development of fishing communities as a whole, consideration need to be given to the provision of fish handling and marketing facilities.

The study concurs with previous research (Pomeroy 2012) that suggests a focus on people and community-related solutions, through an integrated, three-fold approach of resource conservation (assessing the relevance of existing regulations on net mesh size, developing new ones), livelihood improvements (supporting type-III households' diversification with training, capacity building, financial support to entrepreneurship and business development) and restructured governance (co-management between government and fishing communities). *Nagaris* should clarify local institutions on the status of aquatic resources, the property rights thereof. They should engage fishing communities towards co-development of common, accepted objectives and adapted measures for resource protection and sustained local fisheries.

Prospects and future research

Overall, the research shows that fishing, although faced with declining catches and income, remains a popular livelihood and activity in Singkarak Lake communities. Knowing that fishers are diverse and develop different livelihood systems, managers and policy makers may develop and implement policies that enable fishers to live the life they prefer (Onyango, 2011a). Yet, proactive policy must consider current changes and dynamics, and prepare for future. Policies must now urgently address the need for lower fishing pressure on Singkarak fish resources, while supporting livelihoods. A massive exit from fishing activities will not happen, and is not even desirable. Policies must accompany a slow dual process of resource protection and possibly recovery, and of livelihood diversification towards both farming and non-farming activities. Approaches should involve fact-finding, information and negotiation about fish resource decline and possible solutions, and incentives and support towards less economic dependency upon fishing, including capacity building, improved access to off-farm markets.

This study has contributed to an improved understanding of the socio-ecological system of small-scale fisheries. However, some knowledge gaps remain. These gaps include a deeper understanding the aquatic resources. There is a need to know whether the resource is actually endangered or becoming endangered, and requires drastic conservation measures. Can the fish resources recover promptly with only some restriction measures on fishing? Time will tell, but specific ecological and biological studies are urgently needed to design adequate policies.

Also, the dynamics, linkages and pathways of livelihood systems have to be studied in more detail. What becomes of those who successfully diversify (type III)? Are there households that definitely quit fishing to farming (type II or even III)?

In any case, future research should seek to encompass the whole socio-ecological system of the Singkarak Lake, including surrounding agricultural land.

References

Abdulai, A., & CroleRees, A. (2001). Determinants of income diversification amongst rural households in Southern Mali. *Food Policy, 26*(4), 437- 452.

Abdullah, T. (1966). Adat and Islam: An Examination of Conflict in Minangkabau. *Indonesia. no. 2*, 1 - 24.

ADB. (1999). *Special evaluation study on the social and environmental impacts of selected hydropower projects*: Operations evaluation office, SS - 36. .

Adrianto, L., Matsuda, Y., & Sakuma, Y. (2005). Assessing local sustainability of fisheries system: a multi-criteria participatory approach with the case of Yoron Island, Kagoshima prefecture, Japan. *Marine Policy, 29*(1), 9-23.

Ahmed, N., Allison, E. H., & Muir, J. F. (2008). Using the sustainable livelihoods framework to identify constraints and opportunities to the development of freshwater prawn farming in southwest bangladesh. *Journal of the World Aquaculture Society, 39*(5), 598-611.

Aigner, D., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics, 6*(1), 21-37.

Aisyah, N., Husein, M. A., Latiff, I., & Mohayidin, G. (2011). Level of technical efficiency of inshore fisheries in Kuala Trengganu. *Economic and technology management review 6*, 83 - 91.

Akpalu, W. (2011). Fisher skills and compliance with effort-limiting fishing regulations in a developing country The case of Ghana. *International Journal of Social Economics, 38*(8), 666 - 675.

Allan, J. D., Abell, R., Hogan, Z. E. B., Revenga, C., Taylor, B. W., Welcomme, R. L., et al. (2005). Overfishing of Inland Waters. *BioScience, 55*(12), 1041-1051.

Allan, J. D., & Flecker, A. S. (1993). Biodiversity conservation in running waters *Bioscience, 43*(1), 32 - 43.

Allison, E. H. (2001). Big laws, small catches: global ocean governance and the fisheries crisis. *Journal of International Development, 13*(7), 933-950.

Allison, E. H., & Ellis, F. (2001). The livelihoods approach and management of small-scale fisheries. *Marine Policy, 25*(5), 377- 388.

Allison, E. H., Ellis, F., Mathieu, L., Musa, A., Mvula, P. M., & Tinch, R. (2002). *Sustainable livelihood strategies from fluctuating fishery resources in Malawi and Indonesia* DFID.

Allison, E. H., & Horemans, B. (2006). Putting the principles of the Sustainable Livelihoods Approach into fisheries development policy and practice. *Marine Policy, 30*(6), 757-766.

Allison, E. H., Horemans, B., & Bene, C. (2006). *Vulnerability Reduction and Social Inclusion: Strategies for Reducing Poverty Among Small-scale Fisherfolk*. Paper presented at the Wetlands, Water and Livelihoods Workshops.

Allison, E. H., & Mvula, P. M. (2002). *Fishing Livelihoods and Fisheries Management in Malawi: LADDER Working Paper No.22*. Norwich, U.K: University of East Anglia.

Amarasinghe, U. S., & De Silva, S. S. (1999). Sri Lankan reservoir fishery: a case for introduction of a co-management strategy. *Fisheries Management and Ecology, 6*(5), 387-400.

Andrew, N., & Evans, L. (2009). *Approaches and Frameworks for Management and Research in Small-scale Fisheries in the Developing World. The WorldFish Center Working Paper 1914*. Penang, Malaysia The World Fish Center

Andrew, N. L., Béné, C., Hall, S. J., Allison, E. H., Heck, S., & Ratner, B. D. (2007). Diagnosis and management of small-scale fisheries in developing countries. *Fish and Fisheries, 8*(3), 227-240.

Anshari, G. Z., Moedjodo, H., Andrijanto, & Suharso, Y. (2005). *Roles of government, scientists and NPOs in the development of Indonesia Lake Vision.* Paper presented at the 11th World Lake Conference, Nairobi, Kenya.

Arifin, B. (2005). *Institutional constraints and opportunities in developing environmental service markets: lessons from institutional studies on RUPES in Indonesia* World agroforestry centre (ICRAF), Southeast asia regional office.

Arsil, P. (1999). *Kajian pemanfaatan sumberdaya ikan bilih (Mystacoleucus padangensis Blkr) di Danau Singkarak, Propinsi Sumatera Barat [The study of bilih fish (Mystacoleucus padangensis Blkr) utilization in Singkarak Lake, West Sumatra Province]*. Institut Teknologi Bandung, Bandung.

Ashley, C., & Carney, D. (1999). *Sustainable livelihoods: lessons from early experience*. London: Department for International Development

Atkinson, T. (1998). *Exclusion, Employment and Opportunity*, London School of Economics.

Atlas, R., & Overall, J. (1994). Comparative evaluation of two superior stopping rules for hierarchical cluster analysis. *Psychometrika, 59*(4), 581 - 591.

Bailey, C. (1982). *Small-scale fisheries of San Miguel Bay, Philippines: occupational and geographic mobility*: Institute of Fisheries Development and Research, College of Fisheries, University of the Philippines In the Visayas, Quezon City, Philippines; International Center for Living Aquatic Resources Management, Manila, Philippines; and the United Nations University, Tokyo, Japan.

Bailey, C., & Jentoft, S. (1990). Hard choices in fisheries development. *Marine Policy, 14*(4), 333-344.

Bailey, K. D. (1994). *Methods of social research* (Fourth ed.): The Free Press.

Barrett, C. B., Bezuneh, M., Clay, D. C., & Reardon, T. A. (2000). *Heterogeneous Constraints, Incentives and Income Diversification Strategies in Rural Africa*.

Barrett, C. B., Reardon, T., & Webb, P. (2001). Nonfarm income diversification and household livelihood strategies in rural Africa: concepts, dynamics, and policy implications. *Food Policy, 26*(4), 315-331.

Battaglia, P., Romeo, T., Consoli, P., Scotti, G., & Andaloro, F. (2010). Characterization of the artisanal fishery and its socio-economic aspects in the central Mediterranean Sea (Aeolian Islands, Italy). *Fisheries Research, 102*(1-2), 87-97.

Bene, C. (2003). When Fishery Rhymes with Poverty: A First Step Beyond the Old Paradigm on Poverty in Small-Scale Fisheries. *World Development, 31*(6), 949-975.

Bene, C. (2009). Are fishers poor or vulnerable? Assessing economic vulnerability in small-scale fishing communities. *Journal of Development Studies, 45*(6), 911 - 933

Bene, C., & Friend, R. M. (2011). Poverty in small-scale fisheries: old issue, new analysis. *Progress in Development Studies, 11*(2), 119-144.

Bene, C., Hersoug, B., & Allison, E. H. (2010). Not by rent alone: Analysing the pro-poor functions of small-scale fisheries in developing countries. *Development Policy Review, 28*(3), 325 - 358.

Bene, C., Mindjimba, K., Belal, E., & Jolley, T. (2000). *Evaluating livelihood strategies and the role of inland fisheries in rural development and poverty alleviation: the case of Yaere flood plains in North Cameroon.* Paper presented at the IIFET 2000.

Bene, C., Mindjimba, K., Belal, E., Jolley, T., & Neiland, A. (2003). Inland fisheries, tenure systems and livelihood diversification in Africa: The case of the Yae´re´ floodplains in Lake Chad Basin. *African Studies, 62*(2), 187-212.

Bene, C., Neiland, A., Jolley, T., Ovie, S., Sule, O., Ladu, B., et al. (2003). Inland fisheries, poverty, and rural livelihoods in the Lake Chad Basin. *Journal of Asian and African Studies, 38*(1), 17-51.

Bene, C., & Obirih-Opareh, N. (2009). Social and economic impacts of agricultural productivity intensification: The case of brush park fisheries in Lake Volta. *Agricultural Systems, 102*(1-3), 1-10.

Bene, C., Steel, E., Luadia, B. K., & Gordon, A. (2009). Fish as the "bank in the water" - Evidence from chronic-poor communities in Congo. *Food Policy, 34*(1), 108 - 118.

Bennett, E., Neiland, A., Anang, E., Bannerman, P., Atiq Rahman, A., Huq, S., et al. (2001). Towards a better understanding of conflict management in tropical fisheries: evidence from Ghana, Bangladesh and the Caribbean. *Marine Policy, 25*(5), 365-376.

Berkademi, W. (2011). *Pengelolaan sumberdaya ikan bilih (Mystacoleucus padangensis Blkr), di Danau Singkarak, Sumatera Barat [Management of bilih fish (Mystacoleucus padangensis Blkr) resource.* Institut pertanian bogor Bogor.

Berkes, F. (1985). Fishermen and 'The Tragedy of the Commons'. *Environmental Conservation, 12*(03), 199-206.

Berkes, F. (2003). Alternatives to conventional management: Lessons from small-scale fisheries. *Environments, 31*(1), 5 - 19.

Berkes, F., Mahon, R., McConney, P., Pollnac, R., & pomeroy, R. (Eds.). (2001). *Managing small scale fisheries: alternative directions and methods*. Canada: International Development Research Center

Birol, E., Karousakis, K., & Koundouri, P. (2006). Using a choice experiment to account for preference heterogeneity in wetland attributes: The case of Cheimaditida wetland in Greece. *Ecological Economics, 60*(1), 145-156.

Boer, R., Bulek, A. A., & Djisbar, A. (2004). *Challenges and Opportunities to Implement RUPES Program at Lake Singkarak.* Paper presented at the Roundtable discussion on hydrological Impacts of forest, agroforestry and upland cropping as a basis for rewarding environmental service providers, Padang, West Sumatra.

BPS. (2010a). *Kabupaten Solok dalam angka 2009 [Solok district in figures 2009]*. Kabupaten Solok: Badan Pusat Statistik Kabupaten Solok

BPS. (2010b). *Kabupaten Tanah Datar dalam angka 2009 [Tanah Datar district in figures 2009]*. Kabupaten Tanah Datar: Badan Pusat Statistik Kabupaten Tanah Datar

Brinson, A. A., Die, D. J., Bannerman, P. O., & Diatta, Y. (2009). Socioeconomic performance of West African fleets that target Atlantic billfish. *Fisheries Research, 99*(1), 55-62.

Brugère, C., Holvoet, K., & Allison, E. H. (2008). *Livelihood diversification in coastal and inland fishing communities: misconceptions, evidence and implications for fisheries management.*

Carney, D., Drinkwater, M., Rusinow, T., Neefjes, K., Wanmali, S., & Singh, N. (2000). *Livelihoods approaches compared: a brief comparison of the livelihoods approaches of the united kingdom for international development (DFID), CARE, OXFAM and the United Nation Development Programme (UNDP).* Paper presented at the Forum on Operationalizing Participatory Ways of Applying Sustainable Livelihoods Approaches: The web-based electronic conference (We b / E - Conference), Italy.

Chambers, R., & Conway, G. R. (1991). *Sustainable rural livelihoods: practical concepts for the 21st century*.

Charles, A. T. (1992). Fishery conflicts: A unified framework. *Marine Policy, 16*(5), 379-393.

Charles, A. T. (1994). Towards sustainability: the fishery experience. *Ecological Economics, 11*(3), 201-211.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research, 2*(6), 429-444.

Chowdhury, M. S. N., Hossain, M. S., Das, N. G., & Barua, P. (2011). Small-scale fishermen along the Naaf River, Bangladesh in crisis: a framework for management *Mesopot. J. Mar. Sci., 26*(2), 146 - 169

Cinner, J. E., Daw, T., & McClanahan, T. R. (2009). Socioeconomic Factors that Affect Artisanal Fishers' Readiness to Exit a Declining Fishery. *Conservation Biology, 23*(1), 124-130.

Cinner, J. E., & McClanahan, T. R. (2006). Socioeconomic factors that lead to overfishing in small-scale coral reef fisheries of Papua New Guinea. *Environmental Conservation, 33*(01), 73-80.

Coates, D. (2002). *Inland capture fishery statistics of Southeast Asia: Current status and information needs*. Bangkok, Thailand: Asia-Pacific Fishery Commission.

Cochrane, K. L. (2002). *A fishery manager's guide book. Management measures and their application*: FAO Fisheries Technical Paper. No. 424. Rome, 231p.

Coelli, T. (1995). Estimators and hypothesis tests for a stochastic frontier function: A Monte Carlo analysis. *Journal of Productivity Analysis, 6*(3), 247-268.

Colin-Castillo, S. (2011). *Measuring technical efficiancy in a small-scale fishery: a causality analysis*. Pennsylvania: Agricultural and Applied Economics Association.

Cooper, W. W., Seiford, L. M., & Tone, K. (2007). *Data envelopment analysis: A comprehensive text with models, applications, references and DEA-solver software*. New York: springer.

Cowx, I. G., & Gerdeaux, D. (2004). The effects of fisheries management practises on freshwater ecosystems. *Fisheries Management and Ecology, 11*(3-4), 145-151.

Cunningham, S. (1994). Fishermen's income and fisheries management. *Marine Resource Economics, 9*, 241 - 252

Cunningham, S., & Whitmarsh, D. (1980). Fishing effort and fisheries policy. *Marine Policy, 4*(4), 309-316.

Davies, S. (1996). *Adaptable livelihoods: coping with food insecurity in the Malian Sahel*. Basingstoke: Macmillan Press Ltd.

Dewi, R. S. (1995). *Pertumbuhan ikan bilih (Mystacoleucus padangensis Blkr) di perairan Danau Singkarak.*

DFID. (1999). *Sustainable Livelihoods Guidance Sheets*. London: Department for International Development (DFID).

DFID. (2002). *Key sheets for sustainable livelihoods*.

Domptail, S., Easdale, M. H., & Yuerlita. (2013). Managing Socio-Ecological Systems to Achieve Sustainability: A Study of Resilience and Robustness. *Environmental Policy and Governance, 23*(1), 30-45.

Doppler, W., & Bauer, S. (Eds.). (2001). *The Socio-Economic Impact of soil Degradation on Upland Farming Systems in west Sumatra, Indonesia* (Vol. 101): Wissenschaftsverlag VAUK.

Dupont, D. P., Grafton, R. Q., Kirkley, J., & Squires, D. (2002). Capacity utilization measures and excess capacity in multi-product privatized fisheries. *Resource and Energy Economics, 24*(3), 193-210.

Ellis, F. (1998). Household strategies and rural livelihood diversification. *Journal of Development Studies*, *35*(1), 1 - 38.
Ellis, F. (1999). *Rural livelihood diversity in developing countries: evidence and policy implications*. London: ODI natural resource perspectives no. 40.
Ellis, F. (2000). The Determinants of Rural Livelihood Diversification in Developing Countries. *Journal of Agricultural Economics, 51*(2), 289 - 302.
Ellis, F., & Bahiigwa, G. (2003). Livelihoods and Rural Poverty Reduction in Uganda. *World Development, 31*(6), 997 - 1013.
Ellis, F., & Freeman, H. A. (2004). Rural Livelihoods and Poverty Reduction Strategies in Four African Countries. *Journal of Development Studies, 40*(4), 1-30.
Ellis, F., Kutengule, M., & Nyasulu, A. (2003). Livelihoods and Rural Poverty Reduction in Malawi. *World Development, 31*(9), 1495 - 1510.
Ellis, F., & Mdoe, N. (2003). Livelihoods and Rural Poverty Reduction in Tanzania. *World Development, 31*(8), 1367 - 1384.
Esmaeili, A. (2006). Technical efficiency analysis for the Iranian fishery in the Persian Gulf. *ICES Journal of Marine Science: Journal du Conseil, 63*(9), 1759-1764.
Esmaeili, A., & Omrani, M. (2007). Efficiency analysis of fishery in Hamoon Lake: using DEA approach. *Journal of Applied Sciences*, *7*(19), 2856 - 2860.
Fabinyi, M. (2010). The Intensification of Fishing and the Rise of Tourism: Competing Coastal Livelihoods in the Calamianes Islands, Philippines. *Human Ecology, 38*(3), 415-427.
FAO-SFLP. (2006). *Contribution of Fisheries to National Economies in West and Central Africa*.
FAO. (1995). Code of conduct for responsible fisheries *Rome, FAO. 41 p.*
FAO. (2003a). *Fisheries Management: The ecosystem approach to fisheries. FAO technical guidelines for responsible fisheries*. Rome, Italy FAO.
FAO. (2003b). *Review of the state of world fishery resources: inland fisheries*. Rome.
FAO. (2005). *Increasing the contribution of small-scale fisheries to poverty alleviation and food security* (technical guidelines). Rome: FAO.
FAO. (2010). *The State of World Fisheries and Aquaculture 2010*. Rome FAO.
Fare, R., Grosskopf, S., & Kokkelenberg, E. C. (1989). Measuring Plant Capacity, Utilization and Technical Change: A Nonparametric Approach. *International Economic Review, 30*(3), 655 - 666.
Fare, R., Grosskopf, S., & Lovell, C. A. K. (1994). *Production Frontiers*. Cambridge: Cambridge University Press.
Fare, R., Grosskopf, S., Kirkley, J. E., & Squires, D. (2001). *Data Envelopment Analysis (DEA): A Framework for Assessing Capacity In Fisheries When Data are Limited* Paper presented at the Tenth Biennial Conference of the International Institute of Fisheries Economics and Trade (IIFET), Oregon, USA.
Farida, Jeanes, K., Kurniasari, D., Widayati, A., Ekadinata, A., Hadi, D. P., et al. (2005). *Rapid hydrological appraisal (RHA) of Singkarak Lake in the context of rewarding upland poor for environmental services (RUPES)*. Bogor, Indonesia ICRAF South East Asia.
Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society, 20*(3), 253 - 290.
Farrugio, H., Oliver, P., & Biagi, F. (1993). An overview of the history, knowledge, recent and future research trends in Mediterranean fisheries. *Sci.Mar., 57*(2 - 3), 105 - 119.
Fauzi. (1995). *Pengaruh salinitas yang berbeda terhadap daya tetas telur ikan bilih (Mystacoleucus Padangensis Blkr).*

Febriamansyah, R., Ifdal, & Helmi. (2004). *Institutional edvelopment of water resource management for the Ombilin-Singkarak sub-basin in West Sumatra Indonesia: A study on role sharing for river basin management*, Padang.
Feeny, D., Berkes, F., McCay, B., & Acheson, J. (1990). The Tragedy of the Commons: Twenty-two years later. *Human Ecology, 18*(1), 1-19.
Fousekis, P., & Klonaris, S. (2003). Technical efficiency determinants for fisheries: a study of trammel netters in Greece. *Fisheries Research, 63*(1), 85-95.
Gabrielsen, P., & Bosch, P. (2003). *Environmental indicators: typology and use in reporting*.
Garaway, C. (2005). Fish, fishing and the rural poor: A case study of the household importance of small-scale fisheries in the Lao PDR. *Aquatic Resources, Culture and Development, 1*, 131 - 144.
García del Hoyo, J. J., Castilla Espino, D., & Jiménez Toribio, R. (2004). Determination of technical efficiency of fisheries by stochastic frontier models: a case on the Gulf of Cádiz (Spain). *ICES Journal of Marine Science: Journal du Conseil, 61*(3), 416-421.
Garcia, S. M., & Charles, A. T. (2007). Fishery systems and linkages: from clockworks to soft watches. *ICES J. Mar. Sci., 64*(4), 580-587.
Geheb, K., & Binns, T. (1997). 'Fishing farmers' or 'farming fishermen'? The quest for household income and nutritional security on the Kenyan shores of Lake Victoria. *African Affairs, 96*(382), 73 - 93.
Ghee-thean, L., Latif, I. A., & Hussein, M. A. (2012). Does Technology and Other Determinants Effect Fishing Efficiency? An Application of Stochastic Frontier and Data Envelopment Analyses on Trawl Fishery. *Journal of Applied Sciences, 12*(1), 48 - 55.
Giupponi, C., Mysiak, J., & Fassio, A. (2004). An integrated assessment framework for water resources management: A DSS Tool and a pilot study application. from The Fondazione Eni Enrico Mattei (FEEM):
Gordon, A., & Pulis, A. (2010). *Livelihood diversification and fishing communities in Ghana's western region*: WorldFish center. USAID Integrated Coastal and Fisheries Governance Initiative for the Western Region, Ghana.
Gordon, H. S. (1954). The Economic Theory of a Common-Property Resource: The Fishery. *Journal of Political Economy, 62*(2), 124 - 142.
Grafton, R. Q., Arnason, R., Bjørndal, T., Campbell, D., Campbell, H. F., Clark, C. W., et al. (2006). Incentive-based approaches to sustainable fisheries. *Canadian Journal of Fisheries and Aquatic Sciences, 63*(3), 699-710.
Guillemot, N., L?opold, M., Cuif, M., & Chabanet, P. (2009). Characterization and management of informal fisheries confronted with socio-economic changes in New Caledonia (South Pacific). *Fisheries Research, 98*(1-3), 51 - 61
Gustam, A. (1995). *Studi reproduksi ikan bilih (Mystacoleucus padangensis Blkr) yang memasuki Sungai Sumpur, Sumani dan yang ada di Danau Singkarak*
Hall, S. J. (2011). Climate Change and Other External Drivers in Small-scale Fisheries: Practical Steps for Responding. In R. S. Pomeroy & N. L. Andrew (Eds.), *Small scale Fisheries Management: Frameworks and Approaches for the Developing World*: CAB International.
Hardin, G. (1968). The tragedy of the commons. *Science 162*, 1243 - 1248.
Heaps, T., & Helliwell, J. (1985). The taxation of natural resources. In A. Auerbach & M. Feldstein (Eds.), *Handbook of Public Economics*. North-Holland, Amsterdam: 1985.

Heazle, M., & Butcher, J. G. (2007). Fisheries depletion and the state in Indonesia: Towards a regional regulatory regime. *Marine Policy, 31*(3), 276-286.

Herrero, I. (2005). Different approaches to efficiency analysis. An application to the Spanish Trawl fleet operating in Moroccan waters. *European Journal of Operational Research, 167*(1), 257-271.

Hill, N. A. O., Rowcliffe, J. M., Koldewey, H. J., & Milner-Gulland, E. J. (2012). The Interaction between Seaweed Farming as an Alternative Occupation and Fisher Numbers in the Central Philippines. *Conservation Biology, 26*(2), 324-334.

Hoff, A. (2007). Second stage DEA: Comparison of approaches for modelling the DEA score. *European Journal of Operational Research, 181*(1), 425 - 435.

Hossain, M. M., Islam, M. A., Ridgway, S., & Matsuishi, T. (2006). Management of inland open water fisheries resources of Bangladesh: Issues and options. *Fisheries Research, 77*(3), 275-284.

Idda, L., Madau, F. A., & Pulina, P. (2009). Capacity and economic efficiency in small-scale fisheries: Evidence from the Mediterranean Sea. *Marine Policy, 33*(5), 860-867.

Idris. (2002). *Analisis kebijakan pemanfaatan sumber daya alam dan lingkungan danau (Studi kasus di Danau Singkarak provinsi Sumatera Barat) [Analysis of developing the utility policies on lake natural resource and environment (A case study in Singkarak Lake West Sumatera Province)]*. Insitut Pertanian Bogor (IPB), Bogor.

IMM, CFDO, & CBNRM-LI. (2005). *Understanding the Factors that Support or Inhibit Livelihood Diversification in Coastal Cambodia. An output from DFID-funded research in Cambodia. IMM Ltd, Exeter, UK*. Renes Driver, Exeter UK: IMM Ltd.

Isaacs, M. (2006). Small-scale fisheries reform: Expectations, hopes and dreams of "a better life for all". *Marine Policy, 30*(1), 51-59.

Islam, M. M. (2011). Living on the Margin: The Poverty-Vulnerability Nexus in the Small-Scale Fisheries of Bangladesh. In S. Jentoft & A. Eide (Eds.), *Poverty Mosaics: Realities and Prospects* Springer.

Joffre, O. M., & Bosma, R. H. (2009). Typology of shrimp farming in Bac Lieu Province, Mekong Delta, using multivariate statistics. *Agriculture, Ecosystems and Environment, 132*(1-2), 153 - 159.

Jorgensen, D. L. (1989). *Participant observation: a methodology for human studies* (Vol. 15): Sage Publication, Inc.

Juita, E. (1995). *Pengaruh Turbiditas terhadap Daya Kelangsungan Hidup Telur Ikan Bilih (Mystacoleucus padangensis Blkr).*

Kahn, J. S. (1976). Tradition, matriliny and change among the Minangkabau of Indonesia. *Bijdragen tot de Taal-, Land- en Volkenkunde, 132*(1), 64 - 95

Kartamihardja, E. S., & Purnomo, K. (2006, 29 - 30 August). *Keberhasilan introduksi ikan bilih (Mystacoleucus padangensis) ke habitatnya yang baru di Danau Toba, Sumatra Utara* Paper presented at the Seminar Nasional Ikan IV, Jatiluhur.

Kato, T. (1989). Different Fields, Similar Locusts: Adat Communities and the Village Law of 1979 in Indonesia. *Indonesia. No. 47*, 89 - 114.

Kent, G. (1997). Fisheries, food security, and the poor. *Food Policy, 22*(5), 393 - 404.

Kirkley, J., Morrison Paul, C., & Squires, D. (2002). Capacity and Capacity Utilization in Common-pool Resource Industries. *Environmental and Resource Economics, 22*(1), 71 - 97.

Kirkley, J., Squires, D., & Strand, I. E. (1998). Characterizing Managerial Skill and Technical Efficiency in a Fishery. *Journal of Productivity Analysis 9*(2), 145 - 160.

Kirkley, J. E., Squires, D., Alam, M. F., & Ishak, H. O. (2003). Excess Capacity and Asymmetric Information in Developing Country Fisheries: The Malaysian Purse Seine Fishery. *American Journal of Agricultural Economics, 85*(3), 647 - 662.

Knudsen, S., Zengin, M., & Koçak, M. H. (2010). Identifying drivers for fishing pressure. A multidisciplinary study of trawl and sea snail fisheries in Samsun, Black Sea coast of Turkey. *Ocean & Coastal Management, 53*(5–6), 252-269.

Kristensen, P. (2004, 27-29 September). *The DPSIR framework.* Paper presented at the workshop on a comprehensive / detailed assessment of the vulnerability of water resources to environmental change in Africa using river basin approach, Nairobi, Kenya.

Kronen, M., Vunisea, A., Magron, F., & McArdle, B. (2010). Socio-economic drivers and indicators for artisanal coastal fisheries in Pacific island countries and territories and their use for fisheries management strategies. *Marine Policy, 34*(6), 1135-1143.

Kumbhakar, S. C., & Lovell, C. A. K. (2000). Stochastic frontier analysis Cambridge University Press, Cambridge.

Kuperan, K., & Abdullah, N. M. R. (1994). Small-scale coastal fisheries and co-management. *Marine Policy, 18*(4), 306-313.

Kurien, J. (1991). *Ruining the Commons and Responses of the Commoners: Coastal Overfishing and Fishermen's Actions in Kerala State, India*. Switzerland: UNRISD.

Leimona, B., Boer, R., Arifin, B., Murdiyarso, D., & von Noordwijk, M. (2006). Singkarak: Combining Environmental Service Markets for Carbon and Watershed Functions? In D. Murdiyarso & M. Skutsch (Eds.), *Community Forest Management as a Carbon Mitigation Option*. Bogor Center for International Forestry Research (CIFOR).

Lovell, C. A. K. (1993). Production Frontier and Productive Efficiency. In H. O. Fried, C. A. K. Lovel & S. S. Schmidt (Eds.), *The Measurement of Productive Efficiency: Techniques and Applications*. New York: Oxford University Press.

Madau, F. A., Idda, L., & Pulina, P. (2009). Capacity and economic efficiency in small-scale fisheries: Evidence from the Mediterranean Sea. *Marine Policy, 33*(5), 860 - 867.

Mahdi, Shivakoti, G., & Schmidt-Vogt, D. (2009). Livelihood Change and Livelihood Sustainability in the Uplands of Lembang Subwatershed, West Sumatra, Indonesia, in a Changing Natural Resource Management Context. *Environmental Management, 43*(1), 84-99.

Maiyarni. (1997). *The analysis study of phytoplankton's structure of Singkarak Lake*

Malmqvist, B., & Rundle, S. (2002). Threats to the running water ecosystems of the world. *Environmental Conservation, 29*(2), 134 - 153

Mangi, S. C., Roberts, C. M., & Rodwell, L. D. (2007). Reef fisheries management in Kenya: Preliminary approach using the driver-pressure-state-impacts-response (DPSIR) scheme of indicators. *Ocean & Coastal Management, 50*(5-6), 463-480.

Marasco, R. J., Goodman, D., Grimes, C. B., Lawson, P. W., Punt, A. E., & Quinn Ii, T. J. (2007). Ecosystem-based fisheries management: some practical suggestions. *Canadian Journal of Fisheries and Aquatic Sciences, 64*, 928-939.

Maravelias, C. D., & Tsitsika, E. V. (2008). Economic efficiency analysis and fleet capacity assessment in Mediterranean fisheries. *Fisheries Research, 93*(1-2), 85-91.

Mathew, S. (2003). Small-scale fisheries perspectives on an ecosystem-based approach to fisheries management. In M. Sinclair & G. Valdimarsson [book chapter]. *Responsible fisheries in the marine ecosystem*(65 - 81), Wallingford, UK and Cambridge, USA: CABI publishing

McClanahan, T., Castilla, J., White, A., & Defeo, O. (2009). Healing small-scale fisheries by facilitating complex socio-ecological systems. *Reviews in Fish Biology and Fisheries, 19*(1), 33-47.
McConney, P., & Mahon, R. (1998). Introducing fishery management planning to Barbados. *Ocean & Coastal Management, 39*(3), 189 - 195.
MEA. (2005). *Ecosystems and human well-being: wetlands and water synthesis*. Washington DC: World Resources Institute.
Mills, D., Béné, C., Ovie, S., Tafida, A., Sinaba, F., Kodio, A., et al. (2011). Vulnerability in African small-scale fishing communities. *Journal of International Development, 23*(2), 308-313.
Narayan, D., Chambers, R., Shah, M. K., & Peteshch, P. (2000). *Voices of the Poor: Crying Out for Change*. New York: NY:Published for the World Bank, Oxford University Press.
Navy, H., & Bhattarai, M. (2009). Economics and livelihoods of small-scale inland fisheries in the Lower Mekong Basin: A survey of three communities in Cambodia. *Water Policy, 11*(SUPPL. 1), 31-51.
Neiland, A. E., Jaffry, S., Ladu, B. M. B., Sarch, M. T., & Madakan, S. P. (2000). Inland fisheries of North East Nigeria including the Upper River Benue, Lake Chad and the Nguru-Gashua wetlands: I. Characterisation and analysis of planning suppositions. *Fisheries Research, 48*(3), 229 - 243.
Nelson, G. C., Bennett, E., Berhe, A. A., Cassman, K. G., Defries, R., Dietz, T., et al. (2005). Chapter 7: Drivers of change in ecosystem condition and services *Ecosystems and Human well-being: scenarios, volume 2*. Washington, DC: Island Press.
Ness, B., Anderberg, S., & Olsson, L. (2007). Structuring problems in sustainability science: The multi-level DPSIR framework. *Geoforum, 41*(3), 479-488.
Njock, J.-C., & Westlund, L. (2010). Migration, resource management and global change: Experiences from fishing communities in West and Central Africa. *Marine Policy, 34*(4), 752 - 760.
Oakerson, R. (1992). Analyzing the commons: a framework. In D. W. Bromley & R. Feeny (Eds.), *Making the Commons Work: theory, practice and policy* (pp. 41 - 59). San Francisco: ICS.
Odada, E. O., Olago, D. O., Kulindwa, K., Ntiba, M., & Wandiga, S. (2004). Mitigation of Environmental Problems in Lake Victoria, East Africa: Causal Chain and Policy Options Analyses. *Ambio, 33*(1 - 2).
Olale, E., & Henson, S. (2012). Determinants of income diversification among fishing communities in Western Kenya. *Fisheries Research, 125–126*(0), 235-242.
Onyango, P. (2011a). Occupation of Last Resort? Small-Scale Fishing in Lake Victoria, Tanzania. In S. Jentoft & A. Eide (Eds.), *Poverty Mosaics: Realities and Prospects in Small-Scale Fisheries* (pp. 97-124): Springer Netherlands.
Onyango, P. (2011b). *Poverty in small-scale fisheries: Governance challenges the lake Victoria fishing communities, Tanzania.* University of Tromsø, Tromsø.
Ostrom, E., Janssen, M. A., & Anderies, J. M. (2007). Going beyond panaceas. *Proceedings of the National Academy of Sciences, 104*(39), 15176-15178.
Pallant, J. (Ed.). (2005). *SPSS survival manual. a step by step guide to data analysis using SPSS version 12. 2nd edition*. Berkshire, United Kingdom: Open University Press, McGraw Hill education.
Panayotou, T. (1982). Management concepts for small-scale fisheries: economic and social aspects. *FAO fisheries technical paper (228): 53p*.

Pascoe, S. (2007). Capacity analysis and fisheries policy: theory versus practice. *Marine Resource Economics*, *22*(-), 83 - 87

Pascoe, S., & Herrero, I. (2004). Estimation of a composite fish stock index using data envelopment analysis. *Fisheries Research, 69*(1), 91-105.

Pascoe, S., Kirkley, J. E., Greboval, D., & Morrison-Paul, C. J. (2003). Measuring and assessing capacity in fisheries. 2. Issues and Methods. *FAO Fisheries Technical Paper. No.433/2. Food and Agriculture Organisation of the United Nations. Rome, Italy*.

Pascoe, S., & Mardle, S. (2003). *Efficiency analysis in EU fisheries: Stochastic Production Frontiers and Data Envelopment Analysis*. Hants, UK: Centre for the Economics and Management of Aquatic Resources (CEMARE), University of Portsmouth.

Patriono, E., Junaidi, E., & Sastra, F. (2010). Fekunditas Ikan Bilih (Mystacoleucus padangensis Blkr.) di Muara Sungai Sekitar Danau Singkarak. *Jurnal Penelitian Sains*, *13*(3 (D)), 55 - 58.

Pauly, D. (1979). *Theory and Management of Tropical Multispecies; Stocks; a Review, with Emphasis on the Southeast Asian Demersal Fisheries.* Manila International Center for Living Aquatic Resources.

Pauly, D. (1997). Small-scale fisheries in the tropics: marginality, marginalization, and some implications for fisheries management In: Pikitch EK, Huppert DD, Sissenwine MP, editors. Global trends: fisheries management. Bethesda, Maryland: American Fisheries Society, 1997. p. 40–9.

Pearse, P. H. (1992). From open access to private property: Recent innovations in fishing rights as instruments of fisheries policy. *Ocean Development & International Law, 23*(1), 71-83.

Perret, S., Anseeuw, W., & Mathebula, N. (2005). *Poverty and livelihoods in rural South Africa. Investigating diversity and dynamics of livelihoods. Case studies in Limpopo*: Kellogg's Foundation / University of Pretoria.

Pittaluga, F., Braimah, L. I., Bortey, A., Wadzah, N., Cromwell, A., Dacosta, M., et al. (2003). *Poverty profile of riverine communities of southern Lake Volta*.

Pizzali, A. F. M. (1988). *Small-scale fish landing and marketing facilities*. Rome: Food and Agriculture Organization of the United Nations

Pollnac, R. B., Pomeroy, R. S., & Harkes, I. H. T. (2001). Fishery policy and job satisfaction in three southeast Asian fisheries. *Ocean & Coastal Management, 44*(7-8), 531-544.

Pomeroy, R. S., Pollnac, R. B., Predo, C. D., & Katon, B. M. (1996). *Impact evaluation of community-based coastal resource management projects in the Philippines*. Manila: ICLARM.

Pomeroy, R., Garces, L., Pido, M., & Silvestre, G. (2010). Ecosystem-based fisheries management in small-scale tropical marine fisheries: Emerging models of governance arrangements in the Philippines. *Marine Policy*, *34*(2), 298-308.

Pomeroy, R., Thi Nguyen, K. A., & Thong, H. X. (2009). Small-scale marine fisheries policy in Vietnam. *Marine Policy, 33*(2), 419-428.

Pomeroy, R. S. (1995). Community-based and co-management institutions for sustainable coastal fisheries management in Southeast Asia. *Ocean & Coastal Management, 27*(3), 143-162.

Pomeroy, R. S. (2012). Managing overcapacity in small-scale fisheries in Southeast Asia. *Marine Policy, 36*(2), 520-527.

Pomeroy, R. S., Katon, B. M., & Harkes, I. (2001). Conditions affecting the success of fisheries co-management: lessons from Asia. *Marine Policy, 25*(3), 197-208.

Purnomo, K., & Kartamihardja, E. S. (2006). *Upaya pemacuan stok ikan bilih rnelalui pengembangan suaka buatan di danau Singkarak*. Paper presented at the Seminar Nasional lkan 1V.

Purnomo, K., Kartamihardja, E. S., & Koeshendrajana, S. (2003a). *Pemacuan stok ikan di danau Singkarak (Surnatera Barat) dan sungai Batanghari (Jambi)*: Pusat Riset Perikanan Tangkap, BRKP, DKP.

Purnomo, K., Kartamihardja, E. S., & Koeshendrajana, S. (2003b, 29 - 30 Agustus). *Pemacuan stok ikan di danau Singkarak (Surnatera Barat) dan sungai Batanghari (Jambi).* Paper presented at the Seminar Nasional Ikan IV, Jatiluhur.

Rakodi, C. (1999). A Capital Assets Framework for Analysing Household Livelihood Strategies: Implications for Policy. *Development Policy Review, 17*(3), 315-342.

Reardon, T. (1997). Using Evidence of Household Income Diversification to Inform Study of the Rural Nonfarm Labor Market in Africa *World Development, 25*(5), 735 - 747.

Reardon, T., Berdegué, J., Barrett, C. B., & Stamoulis, K. (2006). Household Income Diversification into Rural Nonfarm Activities. In S. Haggblade, P. Hazell & T. Reardon (Eds.), *Transforming the rural nonfarm economy*. Baltimore: Johns Hopkins University Press.

Reardon, T., Delgado, C., & Matlon, P. (1992). Determinants and effects of income diversification amongst farm households in Burkina Faso. *The Journal of Development Studies*, *28*(2), 264-296.

Reardon, T., Taylor, J. E., Stamoulis, K., Lanjouw, P., & Balisacan, A. (2000). Effects of Non-Farm Employment on Rural Income Inequality in Developing Countries: An Investment Perspective. *Journal of Agricultural Economics, 51*(2), 266-288.

Revenga, C., & Kura, Y. (2003). *Status and Trends of Biodiversity of Inland Water Ecosystems*. Secretariat of the Convention on Biological Diversity, Montreal, Technical Series no. 11

Robards, M. D., & Greenberg, J. A. (2007). Global constraints on rural fishing communities: whose resilience is it anyway? *Fish and Fisheries, 8*(1), 14-30.

Ruddle, K. (1994). *A Guide to the Literature on Traditional Community-based Fishery Management in the Asia-Pacific Tropics*. Rome: FAO.

Ruddle, K., & Hickey, F. (2008). Accounting for the mismanagement of tropical nearshore fisheries. *Environment, Development and Sustainability, 10*(5), 565-589.

Ruggiero, J. (2000). Measuring technical efficiency. *European Journal of Operational Research, 121*(1), 138-150.

Salas, S., Bjørkan, M., Bobadilla, F., & Cabrera, M. (2011). Addressing Vulnerability: Coping Strategies of Fishing Communities in Yucatan, Mexico. In S. Jentoft & A. Eide (Eds.), *Poverty Mosaics: Realities and Prospects in Small-Scale Fisheries* (pp. 195-220): Springer Netherlands.

Salas, S., Chuenpagdee, R., Seijo, J. C., & Charles, A. (2007). Challenges in the assessment and management of small-scale fisheries in Latin America and the Caribbean. *Fisheries Research, 87*(1), 5 - 16.

Sarch, M.-T. (1996). Fishing and Farming at Lake Chad: Overcapitalisation, Opportunities and Fisheries Management. *Journal of Environmental Management, 48*(4), 305 - 320.

Sarch, M. T., & Allison, E. H. (2000). *Fluctuations in Africa's inland fisheries: well-adapted livelihoods, maladapted management* Paper presented at the Biennial conference of the international institute for fisheries, economics and trade

Sarch, M. T., & Allison, E. H. (2001). *Fluctuating Fisheries in Africa's Inland Waters: Well Adapted Livelihoods, Maladapted Management.* Paper presented at the Tenth

Biennial Conference of the International Institute ofFisheries Economics and Trade, Oregon, USA.
Schrevel, A., & Kumar, R. (2010). *The Livelihoods concept integrated into the DPSIR analytical tool*. [Wageningen]: Alterra [etc.].
Sen, S., & Raakjaer Nielsen, J. (1996). Fisheries co-management: a comparative analysis. *Marine Policy, 20*(5), 405-418.
Sesabo, J. K., & Tol, R. S. J. (2007). Technical efficiency of small-scale fishing households in Tanzanian coastal villages: an empirical analysis. *African Journal of Aquatic Science, 32*(1), 51-61.
Sievanen, L., Crawford, B., Pollnac, R., & Lowe, C. (2005). Weeding through assumptions of livelihood approaches in ICM: Seaweed farming in the Philippines and Indonesia. *Ocean & Coastal Management, 48*(3–6), 297-313.
Smit, B., & Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Global Environmental Change, 16*(3), 282-292.
Smith, I. R. (1979). *A Research framework for traditional fisheries*. Manila: International Center for Living Aquatic Resources Management,.
Smith, L. E. D., Khoac, S. N., & K.Lorenzen. (2005). Livelihood functions of inland fisheries: policy implications in developing countries. *Water Policy, 7*(-), 359 - 383.
Sowman, M. (2006). Subsistence and small-scale fisheries in South Africa: A ten-year review. *Marine Policy, 30*(1), 60-73.
Ssentongo, G. W. (1989). *Managament of fish stocks and fisheries of deep and shallow lakes of Eastern/ Central/ Southern Africa. UNDP/FAO Regional project for inland fisheries planning (IFIP). RAF/87/099-WP/02/89 (En).*
Stark, O. (1991). *The migration of labour*. Cambridge: Basil Blackwell.
Stobutzki, I. C., Silvestre, G. T., & Garces, L. R. (2006). Key issues in coastal fisheries in South and Southeast Asia, outcomes of a regional initiative. *Fisheries Research, 78*(2-3), 109-118.
Subagyono, K., Kartiwa, B., Sosiawan, H., Surmaini, E., & Susanti, E. (2008). Hydro-metrological characteristics for sustainable land management in the Singkarak Basin, West Sumatra. *Jurnal meteorologi dan geofisika, 9*(1), 65 - 77.
Sulawesty, F., Sunanisari, S., Mulyana, E., Syawal, M. S., Nomosatryo, S., & Fauzi, H. (2002). *Evaluasi kondisi limnologi Danau Singkarak.* Paper presented at the Seminar Nasional Limnologi, Bogor.
Sulawesty, F., Sunanisari, S., Nomosatryo, S., Mulyana, E., Syawal, M. S., & fauzi, H. (2001). *Kondisi limnologi Danau Singkarak [Limnology condition of Singkarak Lake]*. Cibinong: LIPI.
Syandri, H. (1996). *Aspek reproduksi ikan bilih, Mystacoleucus padangensis bleeker dan kemungkinan pembenihannya di Danau Singkarak* Institut Pertanian Bogor Bogor
Syandri, H. (2002). Uji coba pembuatan suaka konservasi ikan di Danau Singkarak. *Laporan kegiatan kerjasama LPPM Universitas Bung Hatta dengan PT.PLN persero, sektor Bukittinggi*
Syandri, H. (2004). Pengelolaan sumberdaya perikanan perairan umum *Pekanbaru: Unri Press*.
Syandri, H., Wira, M., & Azrita. (2002a). Kebijakan pengelolaan plasma nutfah ikan bilih (Mystacoleucus padangensis Blkr) endemic di danau Singkarak. *Prosiding seminar nasional limnology, Lembaga ilmu pengetahuan Indonesia* (Pusat penelitian Limnologi), 325 - 335
Syandri, H., Wira, M., & Azrita. (2002b). Ujicoba pembenihan plasma nutfah ikan bilih (Mystacoleucus padangensis Blkr) endemic di danau Singkarak untuk restocking.

Laporan kegiatan kerjasama LPPM Universitas Bung Hatta dengan PT. PLN (Persero), sektor Bukittinggi.

Tabachnick, B. G., & Fidell, L. S. (Eds.). (2001). *Using multivariate statistics* (Vol. 4th edition). Boston: Allyn and Bacon.

Thorpe, A., Reid, C., van Anrooy, R., & Brugere, C. (2005). When fisheries influence national policy-making: an analysis of the national development strategies of major fish-producing nations in the developing world. *Marine Policy, 29*(3), 211 - 222.

Tingley, D., Pascoe, S., & Coglan, L. (2005). Factors affecting technical efficiency in fisheries: stochastic production frontier versus data envelopment analysis approaches. *Fisheries Research, 73*(3), 363 - 376.

Tzanatos, E., Dimitriou, E., Katselis, G., Georgiadis, M., & Koutsikopoulos, C. (2005). Composition, temporal dynamics and regional characteristics of small-scale fisheries in Greece. *Fisheries Research, 73*(1-2), 147 - 158.

Tzanatos, E., Dimitriou, E., Papaharisis, L., Roussi, A., Somarakis, S., & Koutsikopoulos, C. (2006). Principal socio-economic characteristics of the Greek small-scale coastal fishermen. *Ocean & Coastal Management, 49*(7-8), 511 - 527.

Ulrich, C., & Andersen, B. S. (2004). Dynamics of fisheries, and the flexibility of vessel activity in Denmark between 1989 and 2001. *ICES Journal of Marine Science, 61*(3), 308 - 322.

UNEP. (2008). *UNEP 2007 annual report*: United Nations Environment Programme.

Vázquez-Rowe, I., Iribarren, D., Moreira, M. T., & Feijoo, G. (2010). Combined application of life cycle assessment and data envelopment analysis as a methodological approach for the assessment of fisheries. *Int J Life Cycle Assess, 15*(-), 272 – 283.

Vestergaard, N., Squires, D., & Kirkley, J. (2003). Measuring capacity and capacity utilization in fisheries: the case of the Danish Gill-net fleet. *Fisheries Research, 60*(2-3), 357 - 368.

von Benda-Beckmann, F., & von Benda-Beckmann, K. (2001). Recreating the nagari: decentralisation in West Sumatra. Max Planck Institute for Social Anthropology.

von Benda-Beckmann, F., & von Benda-Beckmann, K. (2004). Struggles over communal property rights and law in Minangkabau, West Sumatra. *Working Papers / Max Planck Institute for Social Anthropology, 64*,

Watkins, M. W. (2000). *Monte Carlo PCA for Parallel Analysis [Computer Software]*. State College, PA: Ed & Psych Assoiates.

Weimin, M., Silva, S. D., & Davy, B. (2010). *Inland Fisheries Enhancement and Conservation in Asia*: FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication 2010/22, 189 pp.

Yuerlita, & Perret, S. R. (2010). Livelihood features of small-scale fishing communities: a case from Singkarak lake, west Sumatra, Indonesia. *International journal of environmental and rural development, 1*(2), 94 - 101.

Appendix 1

Household Survey Questionnaire

Combined Assessment of Ecosystem Services and Livelihoods: an Integrated Social Ecological Approach in Singkarak Lake, West Sumatra, Indonesia.

Enumerator :
Date/month/year :
Sub district/Nagari/Jorong :
Place of interview :

General information of respondent and structure of households

1. Respondent's name : ___________________________

2. Status in family : 1. HH's head 2. Wife 3. Child

3. Domicile information : 1. originally born and stay in the *nagari*
   2. Migrate, from___________________________________
   Reason: ____

4. Number of Households currently resident: _____

5. Households currently resident

No	Name	Age (years)	Sex	Relationship with HH's head	Highest completed education level	Main occupation	Type of activities employed
		< 20 20 – 30 31 – 40 41 – 50 51 – 60 > 60	Male female	head wife husband son/ daughter son/daughter in law grand children Others specify…..	Uneducated Primary school Junior high school Senior high school Diploma Bachelor Master Doctoral Others, specify	Child School Household work Farmer Fishers Govt. officer Private sector Merchant Others specify……	Fishing Farming Grazing Cooking Childcare Washing Cleaning Fetching water Chopping firewood Serving foods
1							
2							
3							
4							
5							
6							
7							

6. Family members permanently/mostly away

No	Name	Age (years)	Sex	Relationship with HH's head	Education level reached	Main occupation
		< 20 20 – 30 31 – 40 41 – 50 51 – 60 > 60	Male female	head wife husband child son/ daughter in law grand children Other relation	Uneducated Primary school Junior high school Senior high school Diploma Bachelor Master Doctoral Other, specify..	Child School Household work Farmer Fishers Govt. officer Private sector Self- employed (non-farm) Others, specify….

7. Family members permanently/mostly away (same people as for previous question)

No	When left	Years away	Current place of residence	Sends money home?	How often	How much (each time)	Total in a year
	Year person left	No of years away	In this district In other city Abroad	Yes No	Every month Once – twice/year 3 - 4 times/year Others……	Amount each time	Calculate amount for year

Total estimated remittances in the past year
Period from ………. to …………..

Household's incomes, assets (livestock, land, housing, credits, savings)

8. What is the main income generating activity of your family?
   1. Fishing
   2. Fish trading
   3. Rice farming
   4. government officer
   5. Private employer
   6. others, ______________________________

9. What are other income generating activities (can be more than one)?

1. Fishing
2. Fish trading
3. Fish processing
4. Livestock
5. Rice farming
6. Collection of foods, fuel woods, etc
7. "Ojek"
8. Others, ____________________________

10. Total households' income per year

Source of income	Amount (Rp)	Who earn the money
Fishermen (lake)*		
Fish ponds		
Rice farming*		
Fruits and vegetables		
Perennial crops		
Gathering woods, bamboo, etc.		
Remittance*		
Wages (agriculture, construction worker)		
Trading		
"Ojek"		
Others, specify…………….		

11. Crop and grazing land owned and operated by household

Area			Ownership	Rent in land	Rent out land	Field cultivated by
Land use	No of plot	Area (Ha)	Owned Heritage Rented in Rented out	Amount paid	Amount received	Jointly Women Men
House						
Garden surrounding the house						
Rice field						
Farm						
Others………						

Total number of plot [ ] total area owned [ ]

Total area used for farming (land rented or borrowed) [ ]

12. Numbers of livestock

Livestock type	Number now	Number one year ago	Number of purchased (past year)	Number sold (past year)	Number consumed (past year)	Current sale price*
Cattle						
Goat						
Sheep						
Chicken						
Duck						

*the price of adult animal that could be obtained now

13. House construction (wall and roof construction are checked from observation)

Wall construction	Roof construction	Water source	Drinkable water	Main electricity
Concrete Brick Wood Brick and wood Hollow brick Others ….	Tiled Corrugated iron Asbestos Thatch Others	Yes No	Yes No	Yes No

14. What is source of energy used for cooking?
    1. Fuel wood 3. Gas 5. Others,__________________
    2. Kerosene 4. Electricity

15. Is there any of household's members belongs to a credit group or scheme?
    1. Yes 2. No

16. If yes, name: ________________, 1. Male 2. Female

17. Name and type of scheme: ____

18. Last amount borrowed (Rp): _______________________

19. Purpose of loan: ______________________________

20. Interest rate: _________________________________

21. Does this scheme also allow for savings?
    1. Yes 2. No

22. Amount (Rp): ___________________

23. How often: _______________

24. Aside from this scheme, does any house member have savings with credit organization or bank?
    1. Yes 2. No

Food security and coping

25. Regular food consumption of household (Amount of rice and other main food consumed per day)

Unit (kg)	Amount	Current price/unit	Value of daily food

26. Response to shocks (last twelve years)

Description of events	Time Date of the event	Effects of even Trapped in debts crop loss animal loss house damage income reduction drop out of school Others…………….	Response to event selling family assets migrated borrowing money from relatives borrowing money from traders change/reduce food consumption Others……………
Flooding			
Drought			
Landslide			
Earthquake			
Fire			
Mount eruption			
Mass conflict			
Family member got sick			
Family member died			
Divorced			

Characteristics of fishing activities

27. How long you have been involved in fishing activity? __________years

28. Why do you choose fishing as your main income source?

1. No land for cultivation
2. High profit
3. Less investment
4. Easy to do
5. Don't have other skills/experience
6. Follow my parents
7. Others,_____________________________

29. Fishing assets (owned or rented by HH's member)

Boat type	Number of unit	Ownership	Main power source	Fishing gears	Number of unit	Ownership
Canoe Others..		Owner Rent Others	Paddle Outboard	Line Trap Net type Cash Gill Seine Lift		Owner Rent Others

30. Please specify fishing gears you usually use

Gear type	Gear size	Water depth (m)	Distance from lakeshore(m)	Type of fish	Amount of catch/gear (liter)	time using the gear throughout the year (month)

31. What are fishing activities and how long do you spend time for fishing per day?

Activities associated with fishing	Duration		Who did the task	
	Start	Finish	Men	Women
Preparing of gear and put the gear in the lake				
Fishing				
Harvesting fish				
Fish scaling				
Fish processing				
Sale/fish marketing				
Meeting related to fisheries				
Maintenance of gear				
Others…………….				

32. Calculation of fishing value (weekly) in periods of time

	Current	5 years ago
How much is the caught per week (liter) = (X)		
How much is the current price from the sale of caught fish (Y)		
Value of fish catch per week = (X) x (Y)		

33. Estimated costs of fishing

Fixed (Rp) = A= Rp………………………									
Type of gear	No of gear	Gear price	Total I (Rp)	No of boat	Boat price	Total II (Rp)	No of engine	Engine price	Total III (Rp)
Total I				Total II			Total III		

Biaya tidak tetap (Rp) = B								
Petrol for engine			Labor/day			Maintc. costs/ year = F	Foods/ drinks = G	Total = D+ E+F +G
No. of unit	Liter/ day	Total= D	No. of labor	Wage/ day	Total =E			

Total costs of fishing (per day) = A + B = ________________

Total costs of fishing (per week) = no of day x total costs/day = ___________________

34. Estimated income from fishing

Income/year			
Fishing value	Operating costs	Net value per week	Pendapatan/minggu x jmlh minggu

35. What do you usually do with your caught?
    1. Only for consumption   3. Consume and sell
    2. Only for selling   4. Others, specify______________

36. How do you sell your caught?
    1. Sell directly to local market   3. Sell to customers within the *nagari*
    2. Sell to the middlemen   4. Others, specify______________

37. Is there any credit-marketing relationship between fishers and middleman?
    1. Yes, how is the credit system: _____________________________________
    2. No

38. Who determine the price of the fish
    1. Fishers   3. Fishers and traders
    2. Traders   4. Others, ___________________________

39. Is there any changes of fish demand
    1. Yes
    2. No

40. If there is change, how is the changes of the demand
    1. Increase
    2. Decrease

41. If there is change, what is the reason of the change?

____

Fishermen's perception on fisheries resource condition

42. What is your opinion regarding fisheries current condition compared to last twelve years
    1. Increase   3. Decrease
    2. Stable   4. Others,_________________________________

43. When did you notice the changes of fisheries condition?

1. < 5 years
2. 5 – 10 years back
3. Last 10 years (since HEPP operation)
4. Don't know
5. Others, specify________________

44. If there is change or not changing of fisheries condition, what are the causes of the change or stability of fisheries condition?

Causes of fisheries resource change	Magnitude of causes				
	Very High	High	Medium	Low	Very low
The decrease of water quality and quantity of the lake and its surrounding					
Construction and operation of HEPP					
The use of fishing gear with small net size					
The use of explosive, poisonous materials					
Lack of socialization of rules/regulation to fishing community					
Lack of coordination between government and fishing community					
Weak law enforcement					
The absent of particular agency to manage fish marketing, trading, fluctuation of fish price					
Others, specify……………………………….					

45. What do you think about the harm of fishing practices to fish resource?

Fishing practices	Harm to juvenile				Damage fish habitat			
	Yes	fair	No	Don't know	Yes	fair	No	Don't know
Use of fishing gears with tiny mesh								
Use explosive and poisonous materials								
Fishing all seasons (unlimited time)								

46. What is the level of your satisfaction to current fisheries condition?

1. High 2. Medium 3. Low 4. Don't know

47. Do you plan to stop fishing and do other income generating activities?

1. Yes, reason____
2. No, reason____

Fishermen’s perception on condition of the lake

48. What are lake’s ecosystem goods and services based on your knowledge?

Jasa lingkungan	Yes	No	Don’t know
Fisheries			
Irrigation			
Food source			
Firewood			
Water supply			
Aesthetic view surrounding the lake			
Recreation			
Spiritual/religious			
Education			
Others			

49. Which of those goods and services directly contribute to your livelihoods and daily activities?____

50. In overall, how do you rate the condition of lake water quality?
    1.Good   2. Fair   3. Poor   4. Not sure

51. What is your perception about the current condition of the lake and its surrounding (last twelve years)

Lake resources	People’s perception				Reasons
	Increase	Stable	Decrease	Others	
Water quality					
Lake level					
Aesthetic view surrounding the lake					
Water catchment condition					
Development activities					

52. Is the current condition of the lake has affected your livelihoods?
    1. Yes   2. No   3. Don’t know

53. If yes, please specify the impacts
    1. Reduced fish catch
    2. Difficult to get water for domestic use particularly for drinking
    3. Damage to rice field during flooding
    4. Others, ____

54. Fishermen’s knowledge on environmental issue and its relationship surrounding Singkarak Lake

Knowledge	Understanding	
	Yes	No
Heavy rain in the upstream causes high turbidity of river water		
Bilih fish like clean and flowing water		
Reduced water quality contribute to decline of *bilih* population		
Domestic, market waste, erosion and other organic materials cause turbidity of lake water		
Trees along riparian zone and forests at the lake catchment reduce flooding even in the heavy rains		
Erosion cause turbidity in river and lake		
Sedimentation reduces lake depth (lake becomes shallow)		
Flooding around the lake damage rice fields		
The use inorganic fertilizer and pesticides increase pollution risk of the lake		
Land use and land cover surrounding the lake determine lake quality water		

55. Do you do any efforts to conserve the lake?
    1. Yes 2. No

56. If yes, please specify kinds of activities you have ever conducted
    1. Actively involved in lake cleaning program
    2. Voluntarily collecting rubbish while fishing
    3. Planting trees or other plants
    4. Others, ____

57. Suppose that the government initiating project implementation soon in Singkarak Lake with the main objective to deal with water quality problem and there will be pooling to get support from community and knowing their willingness to pay to support the project. Which choices you would prefer:
    1. Pay no money and do not recover lake water quality which means letting water quality deteriorate.
    2. Pay certain amount of money for the improvement of water quality and aesthetic view of the lake.

58. If you choose 1 for question 57, what is the reason
    1. Don’t need to improve water quality because current condition is still fine
    2. Don’t have money to pay because of my low income
    3. It is not my responsibility
    4. Others, specify: ____

59. If you choose 2 for question 57, the improvement of water quality will be for whom
    1. For yourself because you can enjoy nice environment
    2. Society because it is the responsibility of all people related to the lake
    3. Future generation, we should sustain the environment for next generation
    4. Others, specify____

Institutional, policy, rules and regulation on fishing activities

60. Are there any rules or regulation implemented in relation to fishing activity in Singkarak Lake?
    1. Yes   2. No   3. Don't know

61. If there are rules or regulation, what are the rules and regulation that you know, please specify

Rules/regulation	Know	Don't know
Prohibition of using explosive, poisonous materials		
Prohibition of using electrical shock		
Those who violating the rules will be punished in jail maximum for 6 years and maximum fined Rp 1,200,000		
Prohibition of fishing in 'bilih' conservation area		
Others,………………………………………………………………		

62. Who involve in decision making process in formulating rules of fishing activity at the Nagari's level? Decision made involve…..
    1. Only Nagari's commission
    2. Nagari's commission and representative from fishing group
    3. Elder respected people and fishermen group
    4. Others,____

63. How do you rate the importance of people's participation in formulation of rules and regulation?
    1. Important   2. Neutral   3. Unimportant   4. Don't know

64. Have you ever been violating the rules or regulation?
    1. Yes   2. Never   3. Don't know

65. If your answer "yes", which rules that you have ever violated?

____

____

66. What is the sanction for violating the rules or regulation?
    1. Warning   3. Imprison   5. Others___________
    2. Confiscation of fishing gear   4. Fined,_Rp______

67. What do you think about the compliance level of fishermen to the existing rules/regulation?
    1. All the fishermen obey the rules
    2. Half of the fishermen obey the rules
    3. Less than half of fishermen obey the rules
    4. More than half of fishermen obey the rules
    5. Every fishermen violating the rules
    6. Others,___________________________________

68. What is your perception on listed rules and regulation on fishing practice?

Rules	Perception			Reasons
	Agree	Neutral	Disagree	
Using net mesh size not smaller than 1 inch				
Prohibition of using explosive material for fishing				
Prohibition of using poisonous and harmful chemicals				
Regulated certain distance from conservation area that is allowed for fishing				

69. Who do you think responsible for fisheries management?

1. Government 3. Sharing and cooperation between government and community
2. Community 4. Others___________________ 5. Don't know

70. What are fisheries problems that you have experienced and suggestions for the solution

Problems	Proposed solution/suggestions	Who should involve

Characteristics of Agricultural Activities Surrounding Singkarak Lake

71. How long you have been engaged in farming or agricultural activity? ________years

72. If the answer for 71 is less than 10 years, what was your job before involve in farming?
____

73. What are division of agricultural tasks in your family

Agricultural task	Duration		Who did the task	
	Start	Finish	Men	Women
Hoeing				
Ploughing				
Weeding				
Sowing				
Mowing				
De-bushing				
Harvesting				
Transporting crops				
Storing crops				
Crops marketing				
Others……………………………………..				

74. Calculation of farming costs

Type of crops	Input 1. Fertilizer 2. Seeds 3. Herbicides 4. Pesticides 5. Labor 6. Plough 7. Others ……	Supplier 1. Local shop 2. Shop in the city 3. Cooperation 4. Individual (friends, neighbor…)	Amount purchased	Price/ unit (Rp)	Total input (Rp)	Marketing costs Transportation Packaging Others
1	1.					
	2.					
	3.					
	4.					
	5.					
	6.					
2	1.					
	2.					
	3.					
	4.					
	5.					
	6.					

75. Crops output and income

Crops name	Total produced (A)	Quantity sold	Price/ unit (B)	Quantity consumed	Gross income C =AxB	Variable costs (D)	Net total income E = C – D	Net cash income F = ExD
1.								
2.								

76. What do you usually do with your crops yields?
1. Sell directly to the local market
2. Sell to the middlemen
3. Only for consumption

3. Sell to customers within the *nagari*
4. Others, specify________________

77. Is there any credit-marketing relationship between farmer and middleman
1. Yes, how is the system, ____
2. No

78. Who determine the price of crops product?
1. Farmers
2. Traders

3. Farmers and traders
4. Others, ___________________________________

Fertilizers and Pesticides Application

79. Rice cropping system
    1. Only rice
    2. Rotation system
    3. Multi-cropping
    4. Others

80. How is the soil condition
    1. Good 2. Moderate 3. Poor

81. Fertilizer application/Ha

Kind of fertilizer	First application		Second application		Pemakaian III		Total (Kg)		Price /Kg
	Rice field	Farming	Rice field	Farming	Rice field	Farming	Rice field	Farming	
Urea									
NPK									
Superphost									
organic fertilizer									
……………									

82. What kind of pesticides that can be used as pest control in your farm?
    1. Rodenticides
    2. Insecticides
    3. Fungicides
    4. Bactericides
    5. Others,________________

83. When did you decide to apply pesticides?
    1. Scheduled base spray
    2. After initial attack
    3. After severe attack
    4. Without observing insect
    5. As per government recommendation
    6. Others,____________________________

84. How often do you use pesticides?
    1. Once a week
    2. Every month
    3. Once in two months
    4. Others,__________________________________

85. Do you have any knowledge on the use of pesticides (dosage, application time, safety shield during the application)?
    1. Yes 2. No

86. If yes, from where do you get pest control advice?
    1. Other farmers
    2. Agricultural extension
    3. Relatives
    4. Pesticides retailer
    5. Pesticides labels
    6. Others,__________

87. What is your opinion about using pesticides in rice intensification?
    1. Important 2. Neutral 3. Unimportant 4. Don't know

88. What is your perception about using pesticides would results in higher yield
    1. Agree 2. Neutral 3. Disagree 4. Don't know

89. Are there any rules or restriction implemented to the farmers in application of fertilizers and pesticides?
    1. Yes, specify____
    2. No
    3. Don't know

90. What is your perception about the rules and regulation
    1. Agree   3. Not sure
    2. Disagree
    3. Reasons: ____

Changes of Livelihoods strategy

91. Is there any new income source activities that currently practiced by local people (it possibly have ever existed before and now more people do the activities or the new activities which has never been practiced)?
    1. Yes, specify____
    2. No
    3. Don't know

92. What do you think about your standard of living during the last twelve years?

Standard of living		Reason
Getting worse		
Fair		
Getting better		

93. If you think that your living standard is getting worse, what do you do to improve it?
____
____

94. What are your strategies to cope with worse living standard such as less income than before:

Men's strategy	Women's strategy

Appendix 2

Correlation matrix of variables for PCA analysis

	Fish assets	Numb boat	Inc fishing	Numb gear	Oprt cost	Land	Inc agric	Farm expr	Age	Fish expr	Numb migrt	Food exp	HH size
Fish assets	1	0.568	0.431	0.449	0.461	0.228	0.066	0.077	-0.035	-0.017	0.016	0.073	0.142
Numb boat	0.568	1	0.369	0.349	0.267	0.069	-0.086	-0.074	-0.058	-0.057	0.078	-0.002	-0.033
Inc fishing	0.431	0.369	1	0.410	0.283	0.064	-0.034	-0.039	-0.037	-0.068	-0.035	0.080	0.075
Numb gear	0.449	0.349	0.41	1	0.139	0.161	-0.042	0.100	0.119	0.041	-0.008	-0.087	-0.041
Oprt cost	0.461	0.267	0.283	0.139	1	0.052	0.003	-0.076	-0.166	-0.071	-0.060	0.074	0.017
Land	0.228	0.069	0.064	0.161	0.052	1	0.699	0.618	0.175	0.056	0.053	0.019	0.172
Inc agric	0.066	-0.086	-0.034	-0.042	0.003	0.699	1	0.596	0.123	0.112	0.041	0.079	0.179
Farm expr	0.077	-0.074	-0.039	0.100	-0.076	0.618	0.596	1	0.329	0.371	0.14	0.106	0.224
Age	-0.035	-0.058	-0.037	0.119	-0.166	0.175	0.123	0.329	1	0.572	0.368	0.033	0.194
Fish expr	-0.017	-0.057	-0.068	0.041	-0.071	0.056	0.112	0.371	0.572	1	0.167	0.019	0.106
Numb migr	0.016	0.078	-0.035	-0.008	-0.060	0.053	0.041	0.140	0.368	0.167	1	0.081	0.224
Food exp	0.073	-0.002	0.080	-0.087	0.074	0.019	0.079	0.106	0.033	0.019	0.081	1	0.529
HH size	0.142	-0.033	0.075	-0.041	0.017	0.172	0.179	0.224	0.194	0.106	0.224	0.529	1

Appendix 3

Technical Efficiency under CRS, VRS and NIRS, Scale efficiency and Return to Scale by Fishers' Type

Type of HH	HH ID	TE-CRS	TE-VRS	SE	TE-NIRS	RTS
Type I	77	100.00	100.00	100.00	100.00	-
	2	85.71	100.00	85.71	85.71	IRS
	3	62.50	76.27	81.95	62.50	IRS
	4	42.86	100.00	42.86	42.86	IRS
	21	37.50	61.01	61.47	37.50	IRS
	20	17.86	50.00	35.72	17.86	IRS
	18	8.93	23.04	38.76	8.93	IRS
	17	20.00	50.00	40.00	20.00	IRS
	8	28.57	55.32	51.64	28.57	IRS
	9	14.29	50.00	28.58	14.29	IRS
	11	28.57	40.91	69.84	28.57	IRS
	59	25.00	52.54	47.58	25.00	IRS
	52	17.50	50.00	35.00	17.50	IRS
	49	21.43	51.02	42.00	21.43	IRS
	145	7.50	33.33	22.50	7.50	IRS
	124	22.50	34.26	65.67	22.50	IRS
	126	52.53	61.57	85.32	52.53	IRS
	135	22.51	38.06	59.14	22.51	IRS
	134	28.75	43.17	66.60	28.75	IRS
	127	17.50	31.55	55.47	17.50	IRS
	129	1.83	33.33	5.49	1.83	IRS
	130	38.53	48.23	79.89	38.53	IRS
	149	25.00	53.08	47.10	25.00	IRS
	141	38.93	48.87	79.66	38.93	IRS
	132	32.22	45.43	70.92	32.22	IRS
	125	100.00	100.00	100.00	100.00	IRS
	140	42.86	53.24	80.50	42.86	IRS
	195	15.00	35.11	42.72	15.00	IRS
	136	50.00	58.67	85.22	50.00	IRS
	196	13.00	29.15	44.60	13.00	IRS
	142	100.00	100.00	100.00	100.00	IRS
	122	100.00	100.00	100.00	100.00	IRS
	121	43.57	51.51	84.59	43.57	IRS
	82	20.00	51.74	38.65	20.00	IRS
	99	37.50	54.12	69.29	37.50	IRS
	107	14.29	50.00	28.58	14.29	IRS
	92	31.79	56.84	55.93	31.79	IRS
	111	15.88	35.75	44.42	15.88	IRS

	112	20.00	37.66	53.11	20.00	IRS
	113	25.00	52.54	47.58	25.00	IRS
	100	25.00	100.00	25.00	25.00	IRS
	198	35.71	45.06	79.25	35.71	IRS
	153	12.50	50.00	25.00	12.50	IRS
	156	11.00	27.86	39.48	11.00	IRS
	162	17.86	31.76	56.23	17.86	IRS
	163	19.16	50.36	38.05	19.16	IRS
	165	7.14	33.33	21.42	7.14	IRS
	173	35.71	100.00	35.71	35.71	IRS
	174	27.07	53.91	50.21	27.07	IRS
	23	50.00	67.38	74.21	50.00	IRS
	179	25.00	53.07	47.11	25.00	IRS
	181	23.56	39.26	60.01	23.56	IRS
	185	28.57	55.77	51.23	28.57	IRS
	186	45.15	54.13	83.41	45.15	IRS
	187	1.07	50.00	2.14	1.07	IRS
	189	21.43	50.94	42.07	21.43	IRS
	190	16.07	30.73	52.29	16.07	IRS
	191	32.47	45.87	70.79	32.47	IRS
	34	17.86	50.00	35.72	17.86	IRS
Mean		**31.86**	**54.01**	**55.31**	**31.86**	
Type II	119	29.02	99.29	29.23	29.02	IRS
	5	100.00	100.00	100.00	100.00	-
	16	58.97	100.00	58.97	58.97	IRS
	19	10.94	50.00	21.88	10.94	IRS
	13	8.93	33.33	26.79	8.93	IRS
	15	14.29	100.00	14.29	14.29	IRS
	45	30.00	100.00	30.00	30.00	IRS
	56	42.68	100.00	42.68	42.68	IRS
	58	58.95	100.00	58.95	58.95	IRS
	60	41.22	100.00	41.22	41.22	IRS
	55	20.41	100.00	20.41	20.41	IRS
	54	46.67	100.00	46.67	46.67	IRS
	36	46.67	100.00	46.67	46.67	IRS
	35	41.26	100.00	41.26	41.26	IRS
	40	50.00	100.00	50.00	50.00	IRS
	38	3.57	100.00	3.57	3.57	IRS
	43	35.00	100.00	35.00	35.00	IRS
	46	100.00	100.00	100.00	100.00	IRS
	150	25.00	100.00	25.00	25.00	IRS
	89	12.50	50.00	25.00	12.50	IRS
	81	35.05	100.00	35.05	35.05	IRS
	86	57.03	100.00	57.03	57.03	IRS
	61	20.48	100.00	20.48	20.48	IRS

	138	60.00	100.00	60.00	60.00	IRS
	139	2.10	100.00	2.10	2.10	IRS
	123	30.00	57.61	52.07	30.00	IRS
	133	12.84	27.70	46.35	12.84	IRS
	131	100.00	100.00	100.00	100.00	-
	66	12.61	100.00	12.61	12.61	IRS
	68	35.00	100.00	35.00	35.00	IRS
	143	5.82	100.00	5.82	5.82	IRS
	75	15.36	100.00	15.36	15.36	IRS
	74	25.71	100.00	25.71	25.71	IRS
	73	35.00	100.00	35.00	35.00	IRS
	72	7.50	33.33	22.50	7.50	IRS
	87	74.23	100.00	74.23	74.23	IRS
	67	54.30	100.00	54.30	54.30	IRS
	71	3.82	50.00	7.64	3.82	IRS
	69	100.00	100.00	100.00	100.00	-
	64	25.67	100.00	25.67	25.67	IRS
	62	52.63	100.00	52.63	52.63	IRS
	28	30.61	100.00	30.61	30.61	IRS
	116	21.43	100.00	21.43	21.43	IRS
	106	32.07	54.79	58.53	32.07	IRS
	117	10.71	43.48	24.63	10.71	IRS
	101	18.37	100.00	18.37	18.37	IRS
	115	35.71	100.00	35.71	35.71	IRS
	114	17.86	100.00	17.86	17.86	IRS
	199	100.00	100.00	100.00	100.00	-
	146	27.62	100.00	27.62	27.62	IRS
	148	12.50	50.00	25.00	12.50	IRS
	151	100.00	100.00	100.00	100.00	-
	152	66.53	100.00	66.53	66.53	IRS
	157	25.00	100.00	25.00	25.00	IRS
	161	100.00	100.00	100.00	100.00	-
	164	20.83	48.99	42.52	20.83	IRS
	169	3.57	36.98	9.65	3.57	IRS
	177	66.64	81.90	81.37	66.64	IRS
	178	44.50	62.62	71.06	44.50	IRS
	188	25.00	100.00	25.00	25.00	IRS
Mean		**38.34**	**88.00**	**42.30**	**38.34**	
Type III	91	57.14	100.00	57.14	57.14	IRS
	120	10.71	50.00	21.42	10.71	IRS
	1	25.00	53.55	46.69	25.00	IRS
	6	19.09	50.00	38.18	19.09	IRS
	7	12.74	50.00	25.48	12.74	IRS
	10	10.83	33.72	32.12	10.83	IRS
	12	35.71	45.95	77.71	35.71	IRS

	14	25.00	100.00	25.00	25.00	IRS
	53	42.11	100.00	42.11	42.11	IRS
	51	80.53	100.00	80.53	80.53	IRS
	50	25.71	100.00	25.71	25.71	IRS
	31	21.43	100.00	21.43	21.43	IRS
	30	12.50	50.00	25.00	12.50	IRS
	33	16.33	100.00	16.33	16.33	IRS
	118	25.51	100.00	25.51	25.51	IRS
	37	2.86	50.00	5.72	2.86	IRS
	39	25.71	100.00	25.71	25.71	IRS
	32	30.00	100.00	30.00	30.00	IRS
	44	54.37	100.00	54.37	54.37	IRS
	41	25.00	100.00	25.00	25.00	IRS
	42	43.06	100.00	43.06	43.06	IRS
	47	19.29	50.00	38.58	19.29	IRS
	48	25.51	100.00	25.51	25.51	IRS
	57	18.37	100.00	18.37	18.37	IRS
	137	17.96	50.00	35.92	17.96	IRS
	63	50.00	100.00	50.00	50.00	IRS
	90	58.31	100.00	58.31	58.31	IRS
	78	50.68	100.00	50.68	50.68	IRS
	79	12.53	50.00	25.06	12.53	IRS
	128	12.50	27.34	45.72	12.50	IRS
	194	25.51	100.00	25.51	25.51	IRS
	76	15.21	100.00	15.21	15.21	IRS
	80	70.43	100.00	70.43	70.43	IRS
	83	25.00	100.00	25.00	25.00	IRS
	84	7.50	33.33	22.50	7.50	IRS
	85	78.42	100.00	78.42	78.42	IRS
	88	81.04	100.00	81.04	81.04	IRS
	70	65.44	100.00	65.44	65.44	IRS
	65	25.00	53.37	46.84	25.00	IRS
	22	54.88	100.00	54.88	54.88	IRS
	26	20.41	100.00	20.41	20.41	IRS
	25	35.00	100.00	35.00	35.00	IRS
	24	51.43	100.00	51.43	51.43	IRS
	27	36.73	100.00	36.73	36.73	IRS
	29	30.00	100.00	30.00	30.00	IRS
	98	10.20	100.00	10.20	10.20	IRS
	94	28.57	100.00	28.57	28.57	IRS
	95	35.71	100.00	35.71	35.71	IRS
	110	18.12	33.57	53.98	18.12	IRS
	103	23.79	100.00	23.79	23.79	IRS
	105	10.71	50.00	21.42	10.71	IRS
	96	17.64	100.00	17.64	17.64	IRS

	109	10.71	33.33	32.13	10.71	IRS
	108	18.49	50.00	36.98	18.49	IRS
	144	14.29	100.00	14.29	14.29	IRS
	104	5.71	50.00	11.42	5.71	IRS
	197	14.29	100.00	14.29	14.29	IRS
	102	10.71	50.00	21.42	10.71	IRS
	97	32.84	44.71	73.45	32.84	IRS
	93	17.86	50.00	35.72	17.86	IRS
	147	71.43	100.00	71.43	71.43	IRS
	154	35.00	100.00	35.00	35.00	IRS
	155	28.57	100.00	28.57	28.57	IRS
	158	35.00	100.00	35.00	35.00	IRS
	159	25.00	100.00	25.00	25.00	IRS
	160	25.51	100.00	25.51	25.51	IRS
	166	41.02	56.44	72.68	41.02	IRS
	167	4.93	50.00	9.86	4.93	IRS
	168	25.26	51.17	49.36	25.26	IRS
	170	14.29	50.00	28.58	14.29	IRS
	171	12.50	34.30	36.44	12.50	IRS
	172	20.41	100.00	20.41	20.41	IRS
	175	100.00	100.00	100.00	100.00	-
	176	23.40	50.00	46.80	23.40	IRS
	180	12.50	50.00	25.00	12.50	IRS
	182	14.29	29.36	48.67	14.29	IRS
	183	7.14	33.33	21.42	7.14	IRS
	184	11.09	33.31	33.29	11.09	IRS
	192	100.00	100.00	100.00	100.00	-
	193	76.87	100.00	76.87	76.87	IRS
	200	82.46	100.00	82.46	82.46	IRS
Mean		**31.17**	**78.36**	**38.95**	**31.17**	